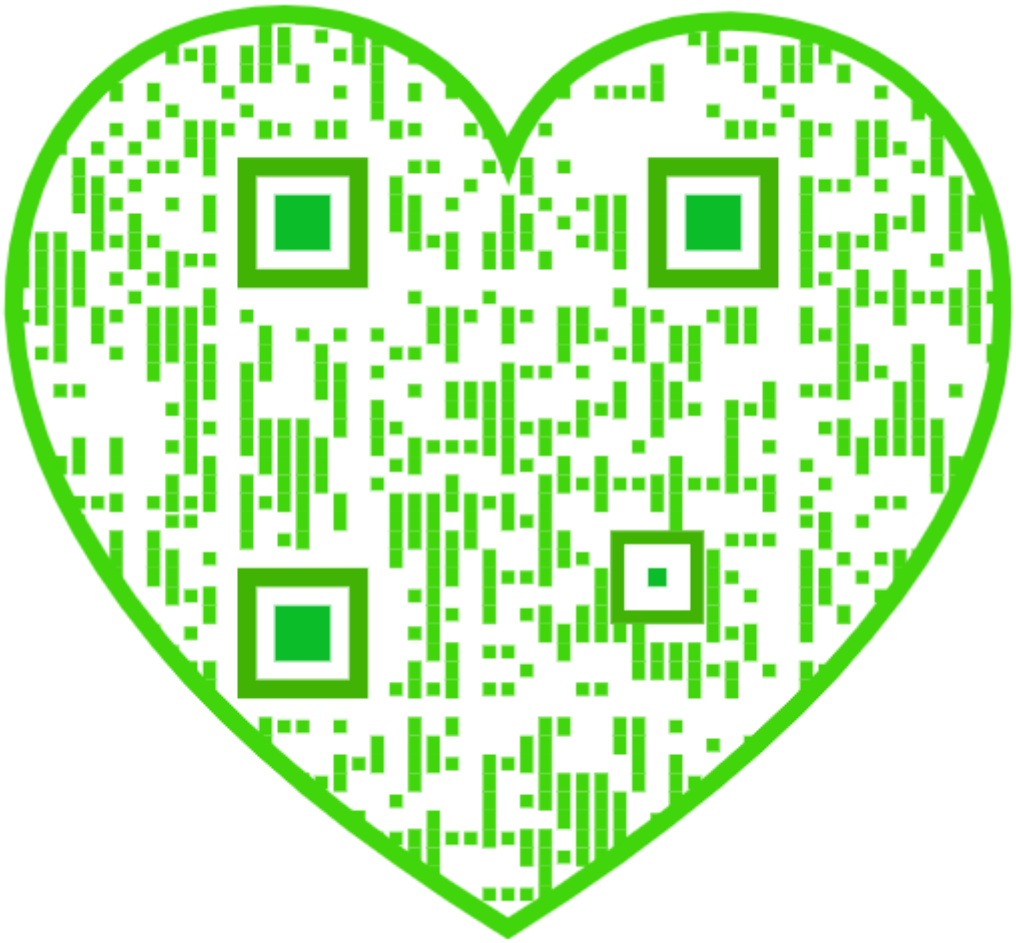
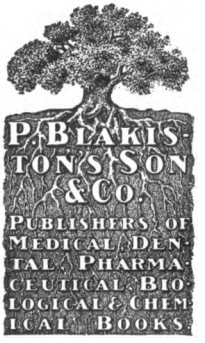



P. BLAKISTON'S SON & CO.
PUBLISHERS OF MEDICAL, DENTAL, PHARMACEUTICAL, BIOLOGICAL & CHEMICAL BOOKS

SPECTACLES

AND

EYEGLASSES

THEIR FORMS MOUNTING AND PROPER ADJUSTMENT

BY

R. J. PHILLIPS, M. D.

OPHTHALMOLOGIST PRESBYTERIAN ORPHANAGE, LATE ADJUNCT PROFESSOR OF DISEASES OF THE EYE, PHILADELPHIA POLYCLINIC AND COLLEGE FOR GRADUATES IN MEDICINE, ETC.

FOURTH EDITION, REVISED

WITH 56 ILLUSTRATIONS

PHILADELPHIA

P. BLAKISTON'S SON & CO.

1012 WALNUT STREET

1909

LANE LIBRARY, STANFORD UNIVERSITY

COPYRIGHT, 1908, BY P. BLAKISTON'S SON & CO

Printed by
The Maple Press,
York, Pa.

Q951
P56
1895

PREFACE TO THE FOURTH EDITION.

New ideas in the construction of spectacles, and especially in the construction of eyeglasses, continue to appear. In the present edition a description of the latest forms and methods of eyeglass fitting has been inserted. In bifocal lenses, also, there are new inventions to be described.

The art of spectacle fitting has greatly improved, and is now better understood than when the first edition of this book was published. Remembering his own novitiate, the author's aim is still to give practical help to the novice in learning the principles which underlie the art and in choosing that form of apparatus which best serves his purpose.

To the manufacturing opticians of his city, and particularly to Mr. A. Reed McIntire, the author wishes to express his obligation for freely imparted information as to processes of manufacture.

February, 1908.

PREFACE TO THE FIRST EDITION.

This little work is the outgrowth of the instruction on the subject of prescribing spectacle frames which has been given to successive classes at the Philadelphia Polyclinic and College for Graduates in Medicine. The book, like the teaching referred to, is intended to supplement studies in refraction, and to give the student that knowledge of the correct placing of the glasses before the eyes without which the most painstaking measurement of the refraction will frequently fail of practical results. With the popularization, as one may call it, of ophthalmology in the profession, many physicians who prescribe glasses are compelled, by the lack of skilled opticians in their neighborhood, to themselves furnish the spectacles to the patient. To these, it is believed, the knowledge which I have endeavored to impart in these pages will prove especially useful.

Of late years much advance has been made in the art of making efficient, comfortable and handsome contrivances for holding glasses before the eyes, and the increased use of prismatic and cylindrical lenses has given the fitting of the frames increased importance. Text-books of refraction remain, however, almost devoid of reference to the subject, the scant literature of which is scattered through opticians' trade publications and a few medical periodicals. Free application has been made to such sources, and the indebtedness incurred duly acknowledged in the text.

My thanks are due to my friend and instructor, Dr.

Edward Jackson, for many valuable suggestions in writing this treatise, and, indeed, for directing my attention to the need of a book on spectacles.

Dr. George M. Gould kindly furnished me with some references used in the introduction, and I am indebted to Messrs. Wall & Ochs, Bonschur & Holmes, and J. W. Queen & Co. for a number of cuts.

CONTENTS.

	PAGE
INTRODUCTION,	1
I. GENERAL CONSIDERATIONS,	9
The Material of Frames,	9
The Component Parts of Spectacles,	11
The Lenses: Their Material and Manufacture,	12
Eye Wires, Temples, and Bridges,	21
The Different Patterns of Spectacles,	21
Bifocal Glasses,	26
The Varieties of Eyeglasses,	30
Spectacles for Cosmetic Effect,	35
II. THE PRINCIPLES OF SPECTACLE FITTING,	36
Centering and Decentering,	36
Prismatic Effect of Decentering,	38
Normal Lateral Centering,	41
Normal Vertical Centering,	43
Distance of the Glasses from the Eyes,	44
Perpendicularity of the Plane of the Lenses to the Visual Axes,	45
Periscopic Glasses,	48
III. PRESCRIPTION OF FRAMES,	51
The Measurements Required,	51
Obtaining the Interpupillary Distance,	54
Height of the Bridge,	57
Relation of the Top of the Bridge to the Plane of the Lenses,	58
Width of Base,	59
Angle of Crest of Bridge,	59
Prescription of Eyeglasses,	62
IV. INSPECTION AND ADJUSTMENT OF SPECTACLES AND EYEGLASSES,	63
Proving the Strength of Lenses,	63
Phacometers,	64
Neutralization of Spherical Lenses,	66

Neutralization of Cylindrical Lenses, ... 67
Neutralization of Sphero-cylindrical Lenses, ... 68
Locating the Optical Center, ... 68
Finding the Apex of a Prism, ... 70
Measuring the Strength of a Prism, ... 70
Detection of Scratches, Specks, Flaws, Etc., ... 77
Irregularity of the Refracting Surfaces, ... 77
Adjusting Spectacle Frames, ... 77
Adjustment of Eyeglasses, ... 83
The Care of Spectacles, ... 87

LIST OF ILLUSTRATIONS.

FIG.		PAGE
1.	Position of the parts of spectacles,	11
2.	Position of the parts of eyeglasses,	11
3.	Sections of lenses,	15
4.	Optician's lens-grinding lathe,	18
5.	Concave toric and concave cylindrical lens,	21
6.	Frameless bifocal spectacles,	22
7.	Forms of spectacle bridges,	23
8.	Ovals, showing the sizes of spectacle eyes,	25
9.	Forms of bifocal glasses,	26
10.	Patterns of lenticular segments,	28
11.	Extra front,	29
12.	Frameless eyeglass,	30
13.	Coil-spring eyeglass,	31
14.	Bar-spring eyeglass,	31
15	Rigid bridge eyeglass,	32
16.	Patterns of the offset guard,	34
17.	Spectacles with lenses decentered "in,"	37
18.	Section of a normally centered lens,	38
19.	Decentered lens, showing prismatic effect,	38
20.	Profile view of the face, showing the "natural" position for the spectacle bridge,	43
21.	Top of bridge "out" from plane of the lenses,	44
22.	Top of bridge "in" from plane of the lenses,	44
23.	Spectacles facing directly forwards,	46
24.	Spectacles facing downwards and forwards,	46
25.	Spectacles facing inwards,	47
26.	Front and back of a convenient spectacle rule,	52
27.	Method of measuring the height of a spectacle bridge,	54
28.	Simplest method of measuring the interpupillary distance,	55
29.	Maddox pupil localizer,	55
30.	Method of using the Maddox pupil localizer,	55
31.	Meyrowitz pupillometer,	56
32.	A common form of pupillometer,	57

33. Method of measuring the distance of the bridge "out," 58
34. Method of measuring the distance of the bridge "in," 59
35. Implement for measuring angle of crest of bridge, ... 61
36. Use of a crest measure, ... 61
37. Mr. Brayton's lens measure, ... 65
38. Apparent displacement of lines caused by rotating a cylinder, . . 67
39. Method of finding the axis of a cylindrical lens, ... 67
40. Ready method of locating the optical center of a lens, ... 69
41. Mode of marking the apex of a prism, ... 70
42. A prism improperly held, ... 70
43. Implement for measuring the refracting angle of prisms, ... 74
44. Method of determining the deviating angle of prisms, ... 75
45. Rotation of a lens within its eye wire, ... 77
46. Bend at the junction of the eye wire and bridge, ... 78
47. Showing the planes of the lenses crossing each other, ... 78
48. Bend of the bridge, ... 79
49. Inequality of corresponding angles of the bridge, ... 79
50. Angles on one side of the bridge too small; on the other too large, . 79
51. Proper fitting of hook temples, ... 81
52. A common but incorrect shape of the nose-pieces of eyeglasses, . . 83
53. Eyeglasses with nose-pieces of correct shape, ... 84
54. Diagram showing inclination of nose-pieces, ... 85
55. Diagram showing inclination of nose-pieces, ... 85
56. The points at which eyeglasses are to be adjusted, ... 86

SPECTACLES AND EYEGLASSES.

INTRODUCTION.

At what time man invented lenses and discovered the aid which they are capable of lending to vision is a matter beyond our knowledge. It is tolerably certain that they were known to civilizations earlier than ours. Though it might be difficult to prove that spectacles were known to the ancients, the evidence in relation to their acquaintance with the essential element of spectacles, the lens, is reasonably convincing. This evidence was, for the most part, discovered by Sir Austen Henry Layard among the ruins of old Nineveh, and is of the most interesting character. Among the articles which he unearthed was a specimen of transparent glass (a small vase or bowl) with a cuneiform inscription fixing its date quite accurately to the latter part of the seventh century B. C. ("Discoveries Among the Ruins of Nineveh and Babylon, etc.," by Austen H. Layard, New York, 1853, p. 196.) This is the most ancient known specimen of transparent glass, though Egypt furnishes it of a date only a century later, and opaque or colored glass was manufactured at a much earlier period, some specimens of the fifteenth century B. C. still enduring. However, the ancient nations were not compelled to wait for transparent glass in order to invent lenses, as they had in rock crystal a material admirably adapted to that purpose, and Layard was so fortunate as to discover such a lens in Nineveh. (*Ibid.*, p. 197.) Sir David Brewster, who examined this lens, described it

as being plano-convex, of a diameter of one and a half inches, and capable of forming a tolerably distinct focus at a distance of four and a half inches from the plane side. It is interesting to note further in regard to this, the oldest lens in existence, that it is fairly well polished, though somewhat uneven from the mode in which it was ground, which Brewster concludes was not upon a spherical surface, but by means of a lapidary's wheel, or some method equally rude. Another evidence of the use of lenses has come down to us from antiquity. Upon record cylinders of old Nineveh, and on engraved gems and stones of Babylon, Egypt, and other sources which long antedate the Christian era, are characters and lines of such delicacy and minuteness as to be undecipherable without the aid of a magnifying lens. Taking these facts in conjunction, the statement that some of the properties of lenses were known to and utilized by the ancients, the old record writers of Assyria, for instance, may be regarded as almost as well demonstrated as though it were made of a modern engraver, and we were to step into his workshop and find his magnifying loup lying beside his work.

The testimony as to their use by the Romans during their supremacy is of a less conclusive character. The statement frequently made that the Emperor Nero used a concave jewel to assist his sight rests upon some obscure sentences in Pliny. That author says: "Nero could see nothing distinctly without winking and having it brought close to his eyes." (Bk. 11, Chap. 54, Riley's Trans.) In another place, speaking of the emerald, *smaragdus*, he says: "In form these are mostly concave, so as to reunite the rays of light and the powers of vision. * * * When the surface of the smaragdus is flat, it reflects the image of objects in the same manner as a mirror. The Emperor Nero used to view the combats of gladiators upon (with, or by means of) a smaragdus." (Bk. 37, Chap. 17.)

The mention of the reflecting properties of the emerald immediately before the statement of Nero's use of it, with the alternative renderings of the Latin ablative, *smaragdo*, make the supposition that Nero used the emerald as an eyeglass uncertain, though in view of his clearly described nearsightedness, the conjecture is probable enough.

Lenses appear to have been unknown in Europe during the first twelve hundred years of the Christian era, though the Saracen Alhazen, who died in Cairo in 1038, has left books showing his acquaintance with them. These books were brought to Europe at a very early period, and the manuscripts yet exist, some in the Bodleian library, and another portion in that of the University of Leyden. They treat with remarkable clarity and accuracy of the laws of reflection and refraction, including reflection and refraction by surfaces convex, concave and cylindrical. Some of their diagrams showing the course of light rays are in use in our text-books at this day. In spite of some errors, they exhibit, also, a good knowledge of the anatomy and physiology of the eye. It was probably from these works that the early writers obtained their first hints of the science of optics, on the revival of learning in the fourteenth and fifteenth centuries. In 1572 a Latin translation of Alhazen's treatise on optics was published at Basle, and in 1600 Johann Kepler, the astronomer, wrote the first European work on the subject. It is worthy of note that Alhazen was born at Bassora, at the head of the Persian Gulf and less than five hundred miles from the spot where, sixteen hundred years before, had stood the palace of the Assyrian kings in the ruins of which Sir Henry Layard found the lens of crystal. It might, perhaps, be plausibly maintained that in the countries about the Tigris some knowledge of optics, and of convex lenses, has persisted without eclipse from the most remote ages.

We are told in a general way that the Chinese have for ages employed spectacles for the relief of defective eyesight. This is, perhaps, to be regarded as only another instance of the exercise of that claim to priority which the Chinese are known to extend over every good and perfect gift. It is known, however, that the countries about the Mediterranean, Greece, Rome and Palestine, each in its day of grandeur, had some intercourse and trade with China. Europe undoubtedly received the science of optics in a fairly advanced state from the Arabs. The Chinese may very well have obtained their knowledge from the same source. So far as is shown by the evidence, the ancient Assyrian was the first to make and use a lens, and the Arab the first to write a scientific treatise on optics.

The earliest European reference to our subject occurs in the writings of Roger Bacon, who died in 1292, and to whom the invention of the instrument he describes is sometimes accredited. Bacon's glass was apparently a large plano-convex lens, probably what we now call a reading glass, intended to be held in the hand, and of it he says: "This instrument is useful to old men and to those that have weak eyes; for they may see the smallest letters sufficiently magnified." Spectacles proper—that is, glasses mounted so as to retain themselves upon the face—appear to have been invented in Florence somewhere between 1280 and the close of the thirteenth century. Dr. Samuel Johnson is said to have expressed surprise that the inventor of such useful articles has found no biographer. Doubtless among the thousands for whom the discovery has kept open the sources of knowledge there would be found one to pay this tribute to the fame of his benefactor were the identity of the latter a matter of certainty. But, unfortunately, our evidence on the point is of the most fragmentary character. The tomb of Salvinus Armatus, a Florentine nobleman who died in 1317, is said to bear an inscrip-

tion to the effect that he was the inventor. If epitaphs enjoyed a less equivocal reputation for truthfulness he would doubtless be held in grateful remembrance as the man who has lengthened youth by postponing old age; and, like Joshua, kept back the night until the day's work was done.

Whoever the inventor, Alessandro di Spina, a monk of Florence who died in 1313, is generally accredited with having made public the use of spectacles, and by several Florentine writers of that time we find them mentioned and recommended. Pissazzo, in a manuscript written in 1299, says: "I find myself so pressed by age that I can neither read nor write without those glasses they call spectacles, lately invented, to the great advantage of poor old men when their sight grows weak." Friar Jordan, of Pisa, in 1305 says that "it is not twenty years since the art of making spectacles was found out, and is, indeed, one of the best and most necessary inventions in the world."

An early mention of spectacles, or, in the language of that time, "a spectacle," occurs in "The Canterbury Tales," where Chaucer makes the Wife of Bath use the metaphor:—

> Povert (poverty) full often when a man is lowe,
> Makith him his God and eek himself to knowe.
> Povert *a spectacle* is, as thinkith me,
> Through which he may his verray (true) frendes se.

There is in existence in the church of Ogni Santi, Florence, an old fresco by Domenico Ghirlandajo, representing St. Jerome, and dated 1480. The Saint is portrayed seated at a desk, apparently deep in the composition of one of the blasts against the Heretics for which he was famous. Upon a peg at the side of the desk, together with the inkhorn and a pair of scissors, hangs a small handleless *pince-nez*. The glasses are round and framed in dark bone, and in the bridge, also of bone, is a hinge. Though the artist seems to have been little impressed by the fact that St.

Jerome died in the year 420, nearly nine centuries before spectacles were invented, the mounting and material represented in these early spectacles are worthy of note as showing their form in Ghirlandajo's time, and probably that in which they originated.

In the early references to spectacles it is the convex lens for the use of the presbyopic which is mentioned. It must have been early discovered that there is a more or less close relation between the age of the wearer and the strength of the convex glass required, and the baneful theory was soon developed that this relation is constant, and that it would be ruinous to use a lens "too old for the eyes," a superstition from which the public is even yet not fully emancipated. We find it rampant in Pepys' time, preventing his oculist, Dr. Turberville,* from giving that gentleman a proper correction for his accommodative asthenopia, of which the diary gives an accurate picture, and losing to the world many a priceless page. Pepys says (June 30, 1668): "My eyes bad, but not worse, only weary with working. * * * I am come that I am not able to read out a small letter, and yet my sight good, for the little while I can read, as ever it was, I think." But Dr. Turberville warns him against glasses too old for him, and so the diary is closed, and Pepys in a last pathetic entry resigns himself to coming blindness; and yet the convex lenses were at his hand, ready to dissipate the mists before him and enable him to "gaze upon a renovated world."

Improvement in spectacles appears to have been slow. The world waited more than two centuries after Kepler for another signal advance. Sir David Brewster is said to have discovered his own astigmatism; that is, he discovered

*Daubigny Turberville; created M.D. at Oxford in 1660. He practiced with great reputation as an oculist in London. His monument yet remains in Salisbury Cathedral, where he was buried.

that vertical and horizontal lines were not equally well seen by him at like distances, but the phenomenon was not explained and the observation faded from view. It remained for George Airy, the astronomer, to rediscover astigmatism, which he did about 1827, to determine that the curvature of the cornea was greater in one diameter than in another at right angles to the first, and to apply the cylindrical lens to the correction of the condition. Mr. Airy's right eye was myopic, while in the left he had compound myopic astigmatism. By a careful comparison of the appearance of objects when viewed with each eye singly, and a study of the effect of concave lenses held before the left eye upon lines crossing each other at right angles, he was able to conclude that the refraction of that eye differed in different planes. Mr. Fuller, an optician of Ipswich, made, under Airy's direction, a concave sphero-cylindrical lens which satisfactorily corrected his refractive error. Thus was the last great discovery in spectacles accomplished—a bit of work for completeness leaving nothing to be desired, and of not sufficiently acknowledged importance to humanity.

Benjamin Franklin invented bifocal spectacles. Since this statement is supposed by many to rest on tradition only, it may be of interest to quote a portion of a letter of Franklin's which bears upon the point. The letter is addressed to George Whately, of London, and is dated Passy, 23d May, 1785. In it Dr. Franklin says: "By Mr. Dolland's saying that my double spectacles can only serve particular eyes, I doubt he has not been rightly informed of their construction. I imagine it will be found pretty generally true that the same convexity of glass through which a man sees clearest and best at the distance proper for reading, is not the best for greater distances. I therefore had formerly two pairs of spectacles, which I shifted occasionally, as in traveling I sometimes read, and often wanted to regard the prospects. Finding this change

troublesome and not always sufficiently ready, I had the glasses cut and half of each kind associated in the same circle. By this means, as I wear my spectacles constantly, I have only to move my eyes up or down, as I want to see distinctly far or near, the proper glasses being always ready. This I find more particularly convenient since my being in France. * * *" ("The Complete Works of Benjamin Franklin." Ed. by John Bigelow, New York, 1888.)

We may infer from the context that the invention took place before Franklin went to France, which was in the latter part of 1776. As he was born in 1706, the necessity for a double glass would first arise about 1750, and the invention therefore took place somewhere between this date and that of the journey to France.

The frames in which spectacles were mounted continued to be very clumsy affairs until the beginning of this century, when light metal frames were introduced in place of the earlier devices of bone, horn, or shell. Their later evolution has generally been along the lines of improved mechanical construction and increased lightness and beauty. It would be difficult to mention an article which plays a more important part in modern life than do spectacles, or one which plays its part more acceptably. It is scarcely possible to estimate them at their true worth, or to imagine our condition without them. Deprived of their aid, most men would be too old for work at fifty, and purblind at sixty. For us all, as an old writer quaintly observes, "they keep the curtain from falling until the play has come to an end."

I. GENERAL CONSIDERATIONS.

By far the most generally useful method of placing glasses before the eyes is by spectacle frames, though the eyeglass, or *pince-nez*, has advantages in some cases, from the facility and quickness with which it may be placed in position or removed. The superiority of eyeglasses in appearance and becomingness is another point not unworthy of consideration, as the glasses will surely be more constantly worn if they are becoming than if they are not so. Moreover, the patient is justly entitled to the correction of his refractive error with as little injury to his appearance as possible. The disadvantages of eyeglasses are, that for constant wear they are seldom so comfortable as spectacles; that on some faces it is nearly impossible to keep them in place; while, where the contained glass is cylindrical or prismatic, the rotary displacement which it is possible for the glass to take is a serious and sometimes fatal objection to their adoption.

Lorgnettes and single eyeglasses, or quizzing glasses, as they are called, are little more than playthings; though sometimes, as in aphakia, or high myopia, a strong convex or concave lens in one of these forms is of use when the spectacles constantly worn do not give the vision which may occasionally be required.

The Material of Spectacle Frames is usually gold, silver, steel, brass gold plated, or alloys containing nickel and tin. Horn, tortoise shell and celluloid find, or have found, a limited applicability in this connection.

Gold, of from 10 to 14 karat, is, by far, the best material for frames. Finer than this it is too flexible, while if less pure it may blacken the skin. In the end, such frames

are cheaper than steel, as, owing to the liability of the latter metal to rust when in contact with the moist skin, the gold will outlast it many times over. In eyeglasses, however, the parts are heavier, and the metal is not in contact with the skin; so that there is not the same liability to rust. The gold frames furnished by opticians in this country usually have a stamp mark on the inner side of the right temple, near the hinge, which denotes the fineness of the gold: thus 8 karat is marked +; 10 karat, θ; 12 karat, *; while 14 karat, or finer, is marked 14k, etc.

Silver and brass are very poor material for frames, being soft, flexible and entirely lacking in elasticity. They are only useful for workmen's protective goggles or some such purpose where very heavy frames are allowable. The various alloys of nickel and tin, sold under trade names, have the faults of silver and brass in less degree. Some of them make fairly satisfactory frames for eyeglasses. For spectacles they are scarcely worth considering.

Gold is, therefore, not only the best but the only good material for frames. A cheap frame having a certain amount of rigidity and elasticity, and free from liability to rust, is still a thing to be desired. Aluminum has been regarded as promising in this connection, but except lightness it has scarcely a quality to recommend it. It is soft, flexible and inelastic, and is readily corroded by the perspiration if the latter happen to be alkaline, which it frequently is. Moreover, aluminum cannot be soldered. In itself, therefore, it is unlikely ever to be available for this purpose. Some of its alloys, however, have interesting properties. That composed of ten parts of aluminum and ninety parts of copper some authorities assert to be the most rigid metal known. It is a red gold color, does not tarnish readily, is lighter than brass or gold, and can be soldered. It is possible that in some such alloy will be

found a material having the valuable properties of gold for this purpose and without the latter's cost.

The Component Parts of Spectacles.—A pair of spec-

FIG. 1.

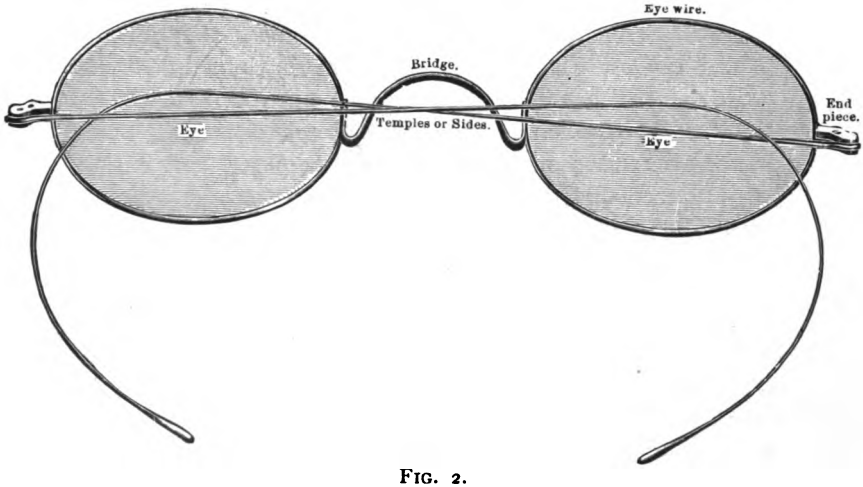
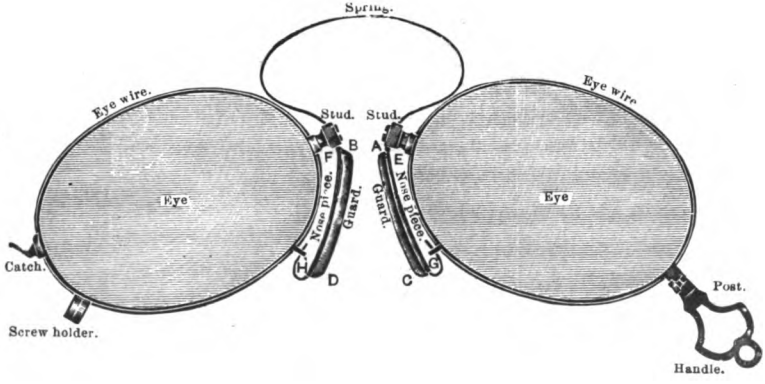


FIG. 2.



tacles is made up of fifteen or seventeen pieces, whose positions are shown in Fig. 1. They are: two lenses, two eye wires, four end pieces, two screws, two pins, or dowels,

two temples, and one bridge. Sometimes the rings upon the temples, through which the dowels pass, are formed as separate pieces. Fig. 2 shows the name and position of each part of an eyeglass. A glance at the more important of the many interesting processes required in making these different parts will contribute to an understanding of the subject.

The Lenses.—The word lens is the Latin name of the lentil, a small bean. The resemblance in shape caused the name to be applied to the optical implement. Spectacle lenses are usually made of glass; sometimes of rock crystal (crystallized quartz). The latter substance has a slightly higher index of refraction, so that a lens of a given strength may be somewhat lighter when made of it than when made of glass. The notion is common that these "pebbles," as they are called, possess a peculiar virtue in strengthening the eyes or in some other direction. I suppose the idea is that, being the product of Nature's laboratory, they are necessarily superior. The advantage which they may have of being slightly lighter and harder than lenses of glass is more than counterbalanced by their higher cost, and by the fact that the index of refraction of rock crystal is not very constant.

Of the different kinds of glass, that known as crown glass is preferred, on account of the superior brilliancy which it possesses. It differs from ordinary sheet glass only in the method of blowing. At one point in the process, the mass of glass on the blowpipe assumes the shape of a crown; hence the name. Although glass is theoretically a definite chemical compound, the different methods of handling make a considerable difference in the product of different makers. It consists chemically of silicic acid united with some two of the metallic bases: sodium, potassium, calcium, magnesium, aluminum, iron, and lead, but owing to impurities in the glassmaker's raw materials, traces of several more of these bases are generally present. The

bases calcium and sodium are those used for ordinary sheet and crown glass; iron, always present as an impurity, giving the product its greenish tinge. To lessen this tint, arsenic is employed as a bleaching agent. Peroxid of manganese is sometimes used for the same purpose, and it is a slight excess of this agent which gives to certain samples of glass their pinkish tint. The transparency of such glass is thought to be less durable than that having the greenish color. For glass for spectacle lenses of the best grade our grinders are still dependent on Europe, no source of supply of a first-class and uniform product having as yet appeared here.

The index of refraction of the varieties of glass used in spectacle making is as follows:

Crown glass.	1.5
Flint glass.	1.57
Ordinary sheet glass.	1.53
Rock crystal.	1.56

The two broad, polished surfaces of a lens are called its refracting surfaces, since it is at these surfaces that the rays of light are refracted when the lens is in use. On the shape of these surfaces, and their position relative to each other, depend all the powers and properties of a lens. Each of these surfaces may be either plane, spherical, or cylindrical. A spherical surface is such a one as, continued in all directions, would form a sphere, and which is, therefore, a segment of a sphere. Similarly, a cylindrical surface is the segment of a cylinder. Spherical and cylindrical surfaces may be either convex or concave. A single surface of a lens may be, therefore, either

Plane,
Convex spherical,
Concave spherical,
Convex cylindrical,
Concave cylindrical.

Since every lens has two refracting surfaces, the list of lenses which it is possible for the lens maker to produce by combinations of these five primary surfaces is as follows:—

1. Prismatic.
2. Plano-convex spherical.
3. Plano-concave spherical.
4. Plano-convex cylindrical.
5. Plano-concave cylindrical.
6. Biconvex spherical.
7. Biconcave spherical.
8. Concavo-convex (two varieties):
   (*a*) Radius of curvature of convex surface greater than that of concave. (Converging meniscus.)
   (*b*) Radius of curvature of convex surface less than that of concave. (Dispersing meniscus.)
9. Sphero-cylindrical (four varieties):
   (*a*) Convex sphere combined with convex cylinder.
   (*b*) Convex sphere combined with concave cylinder.
   (*c*) Concave sphere combined with concave cylinder.
   (*d*) Concave sphere combined with convex cylinder.
10. Biconvex cylindrical, axes coincident.
11. Biconvex cylindrical, axes crossed.
12. Biconcave cylindrical, axes coincident.
13. Biconcave cylindrical, axes crossed.
14. Concavo-convex cylindrical, axes coincident.
15. Concavo-convex cylindrical, axes crossed.

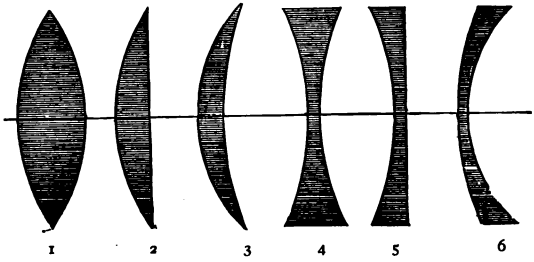
Sections of lenses are shown in Fig. 3, each section illustrating two or more lenses, accordingly as we regard the curved lines as sections of spheres, or cylinders, and the straight lines as planes, or as sections of cylinders in the direction of their axes.

Lastly, the prism may be introduced as an element into each of these lenses. Thus we have quite a long list of the possible forms of the lens, and that without considering the

"toric" surface, which will be spoken of later. Of these lenses only the nine first mentioned, and the combination of some of them with the prism, are in practical use. The others, the bicylindrical lenses, besides being difficult of manufacture, have each its optical equivalent in some simpler form of lens, either plano-cylindrical or sphero-cylindrical. They are only mentioned now because their use has been advocated by a few writers in the past.

Difficulties in grinding, and the near equivalence of certain of the lenses mentioned among the first nine of our list, render the use of some of these lenses quite rare. It is, for instance, more difficult to grind a perfect plano-

FIG. 3.



spherical lens than it is to grind a bispherical, and as in weak lenses, such as are used in spectacles, the action of every plano-spherical lens can be nearly exactly duplicated by some bispherical one, we seldom find plano-spherical lenses in use. Among sphero-cylindrical lenses also it is usual to consider certain combinations as equivalent to each other. For example, a convex spherical combined with a convex cylindrical, as equivalent to some stronger convex spherical combined with a concave cylinder. These lenses are only strictly equivalent, however, for a small area near their optical centers. When their influence on the field of vision is taken into account, they can no longer be consid-

ered identical, as we shall see in considering periscopic lenses.

In Fig. 3, the first three lenses shown act as convergers of rays, and are all considered as convex, or "plus" lenses,

TABLE I.

OLD SYSTEM.				NEW SYSTEM.			
I. No. of the Lens, Old System	II. Focal Distance in English inches.	III. Focal Distance in Milli-meters.	IV. Equiva-lent in Diopters.	V. No. of the Lens, New System	VI. Focal Distance in Milli-meters.	VII. Focal Distance in English inches.	VIII. No. corres-ponding of the Old System.
72	67.9	1724	0.58	0.25	4000	157.48	166.94
60	56.6	1437	0.695	0.5	2000	78.74	83.46
48	45.3	1150	0.87	0.75	1333	52.5	55.63
42	39.6	1005	0.90	1	1000	39.37	41.73
36	34	863	1.16	1.25	800	31.5	33.39
30	28.3	718	1.39	1.5	666	26.22	27.79
24	22.6	574	1.74	1.75	571	22.48	23.83
20	18.8	477	2.09	2	500	19.69	20.87
18	17	431	2.31	2.25	444	17.48	18.53
16	15	381	2.6	2.5	400	15.75	16.69
15	14.1	358	2.79	3	333	13.17	13.9
14	13.2	335	2.98	3.5	286	11.26	11.94
13	12.2	312	3.20	4	250	9.84	10.43
12	11.2	287	3.48	4.5	222	8.74	9.26
11	10.3	261	3.82	5	200	7.87	8.35
10	9.4	239	4.18	5.5	182	7.16	7.6
9	8.5	216	4.63	6	166	6.54	6.93
8	7.5	190	5.25	7	143	5.63	5.97
7	6.6	167	5.96	8	125	4.92	5.22
6½	6.13	155	6.42	9	111	4.37	4.63
6	5.6	142	7.0	10	100	3.94	4.17
5½	5.2	132	7.57	11	91	3.58	3.8
5	4.7	119	8.4	12	83	3.27	3.46
4½	4.2	106	9.4	13	77	3.03	3.21
4	3.8	96	10.4	14	71	2.8	2.96
3½	3.3	84	11.9	15	67	2.64	2.8
3¼	3.1	79	12.7	16	62	2.44	2.59
3	2.8	71	14.0	17	59	2.32	2.46
2¾	2.6	66	15.1	18	55	2.17	2.29
2½	2.36	60	17.7	20	50	1.97	2 09
2¼	2.1	53	18.7				
2	1.88	48	20.94				

being designated by the sign +, or sometimes by cx. The remaining lenses in the figure act as dispersers of the rays and are known as "minus," or concave lenses, and receive the sign —, or sometimes cc. For the terms,

spherical lens, cylindrical lens, prismatic lens, sphero-cylindrical lens, etc., the words sphere, cylinder, prism, spherocylinder, etc., are frequently employed and are unobjectionable. Finally, the sign ⊂ is used for "combined with" in the formula of a combination lens, as + 4. sphere ⊂ + 2. cylinder.

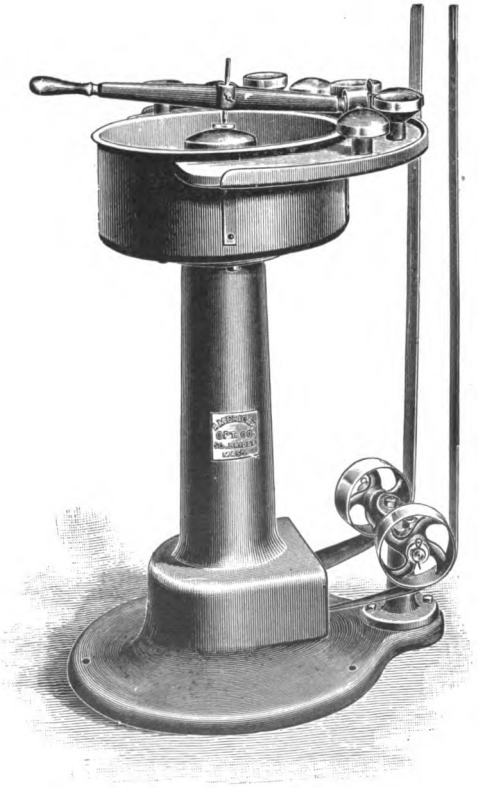
The new system of numbering lenses, the dioptric system, has so entirely fulfilled the requirements of the users of lenses, and has so simplified and facilitated our every-day work and calculations, that the old or inch system of numbering is rapidly becoming of historical interest only. As its use, however, still survives in certain quarters, and lenses are frequently met with which are marked by this system, a table showing the equivalence of the ordinary lenses of the test case in the two systems is shown on page 16. It is calculated for an index of refraction of 1.53.

The simple apparatus used for grinding a single spherical lens is shown in Fig. 4. The disk of glass of which a lens is to be made is fastened, by means of pitch, to a small, cubical block of iron having a pit in the surface opposite that to which the glass is fastened. Into this pit fits a pin upon a lever, which is in the hand of the workman. When the free surface of the glass is applied to the surface of the "tool" to whose form it is to be ground, it, together with the block of iron, turns upon the pin. The universal joint at the end of the lever permits lateral and vertical movements, so that the workman is able to carry the glass freely over all portions of the tool.

The tool which gives the shape to the surface of the glass is made of steel; and for spherical glasses is in the form of a disk, with its surfaces looking upward and downward, and revolving about a vertical axis, like a potter's wheel. The upper surface of this disk is convex for grinding concave glasses, or concave for grinding convex glasses. Of course, each strength of lens requires a separate tool

having the requisite convexity or concavity of surface. The abrading material placed upon the surface of the tool is wet, powdered emery of successively finer and finer grades

FIG. 4.



OPTICIAN'S LATHE FOR GRINDING SPHERICAL LENSES.

until the desired amount of glass has been ground away. When this process is complete, the surface of the glass has the desired spherical curvature, but it is rough: that is, it is

"ground glass." To polish it, a piece of wet broadcloth or felt is smoothly applied to the surface of the tool upon which the glass was ground, conforming, of course, to that surface. The cloth, being sprinkled with wet "rouge" (a carefully calcined sulphate of iron), gives the glass held against it a beautiful polish without altering its spherical curvature. The same processes must now be gone over with the other surface of the lens, after which it is cleaned and cut to a shape suitable for its future mounting.

This is done by means of an implement called a lens-cutter, in which the lens rests on a leather cushion and is held firmly in position by a rubber-tipped arm, while a diamond-tipped glass-cutter, guided by a pattern, traces the oval or other desired outline upon the glass. The superfluous glass is removed piecemeal by means of pincers, and the lens passes to the next process, which is the smoothing and, if necessary, beveling of the edges. This is done by hand upon large Scotch grindstones. If the lens is to be mounted in a round eye wire, its edge must be grooved by means of a file, while a skeleton frame will require the drilling of the glass, which may be done by hand with a steel drill or by a special machine.

In grinding a cylindrical lens the surface of the tool is, of course, a portion of the surface of a cylinder, and the glass is ground by a to-and-fro motion. It is evident that the axis of the cylinder in the future spectacle need not be taken into account in grinding, but only in the process of cutting to shape for mounting.

When the lenses are of high power it is of advantage that they be made in the form of a meniscus, giving what are known as periscopic glasses. For instance, if a + 4. diopter lens is required, the anterior surface is ground to a + 6. D. and the posterior surfaces to a — 2. D. It is just as advantageous to a cylindrical or sphero-cylindrical glass to be periscopic as it is to a spherical, but under present

LANE LIBRARY ... UNIVERSITY

methods of grinding it is manifestly impossible to give them this form, as the cylinder is ground on one side, and the other ground to a plane or sphere, as the case may be. Glasses which overcome the difficulty have, however, been made, and were described by Dr. George C. Harlan at the meeting of the American Ophthalmological Society in 1885, and again in 1889. From the latter communication I quote the following description of the glass:

"The lens to which I wish again to call the attention of the Society consists of crossed cylinders ground on one surface of the glass, the other being left for any desired spherical curve. In this way a meniscus may be produced. Here, for instance, is a combination lens giving the effect of + 4. ⊂ + 2. Cyl. To produce this effect crossed cylinders of + 4. and + 6. are required, supposing the other surface of the glass to be left plain. If we wish to give the periscopic form to this glass, it can be done by making the cylinders 6 and 8, and grinding a — 2. sphere on the other side. If a simple cylinder is needed, the spherical curve must equal that of the weaker cylinder.

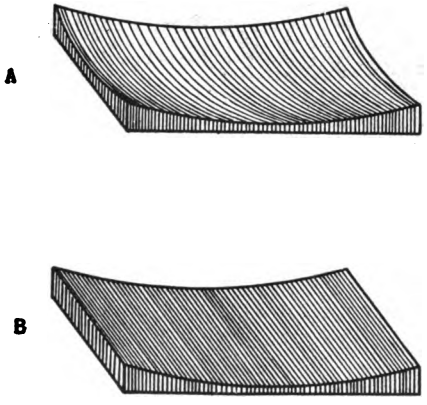
"I learn from a recent publication by Dr. George J. Bull, of Paris, entitled 'Lunettes et Pince-nez,' that glasses similar to these have been made with more or less success before, but have never come into general use. Dr. Bull describes them under the name of '*verres toriques*.' The tore (Latin *torus*) is the surface engendered by a circle which turns about an axis situated on the plane of the circle. A familiar example of the torus is the circular convex molding at the base of an architectural column. A glass ground upon a wheel having this form will present two cylindrical curves at right angles to each other, one depending on the radius of the wheel, and the other on the radius of the convexity of its rim. It would seem that 'toric lenses' is the proper designation of these glasses." Fig. 5, A, represents a concave toric lens. In the same

figure, B is a concave cylindrical lens, introduced for the sake of comparison.

Those who have used these glasses consider them much more satisfactory than glasses made by the common method, and they should be borne in mind when prescribing for high astigmatism in patients who use their eyes a great deal for work requiring accuracy.

Eye Wires, Temples, and Bridges.—Eye wires are made by wrapping the untempered wire, in the form of a spiral, closely about a flattened metal cylinder. Being tempered

FIG. 5.

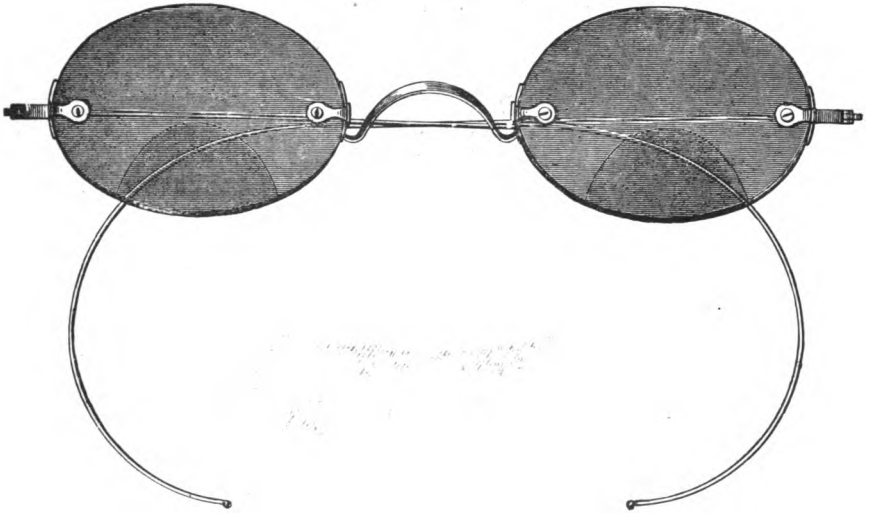


while in this position, the loops of the spiral will retain the shape given them. A single cut down the side of the cylinder converts each loop into a separate oval ring. End pieces and straight temples are stamped from sheets of metal, and afterward formed and tempered. Hook temples of steel are turned from wire upon a lathe. Bridges are usually made of oval or half-oval wire, and are simply pressed to the desired shape by a forming machine.

Of the Different Patterns of Spectacles.—In the common and strongest form of spectacle, the edge of the glass

is beveled so as to enter a groove in the wire which surrounds it. In a second form, in which the edge of the glass is grooved for the reception of a fine, round wire, the object sought, of rendering the rim of the spectacles less conspicuous, is generally defeated by the fact that the glass must be made thicker than it otherwise need be, in order to give room for the groove on its edge. In concave glasses this is not the case, since the edge of the glass is here the thickest

FIG. 6.

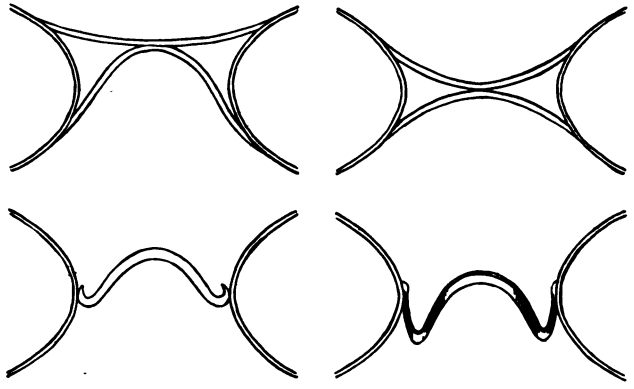


part, and such glasses may sometimes be mounted in this way with advantage. In a third form, called "frameless" spectacles (Fig. 6), the wire encircling the glass is dispensed with altogether, small holes being drilled through the glass near its edge for the accommodation of screws which fasten the bridge and temples in place. The advantages of this form are its beauty and inconspicuousness. It should never be prescribed for children, as it is quite

liable to break at the point where the glass has been drilled. The edges of these glasses should not be polished, but should be given a dull finish, otherwise they reflect the light disagreeably.

Sides, or temples, have been variously constructed. Those having sliding and turn-pin joints are examples of antiquated forms. Those now used are the "hook," or "riding-bow," and the plain, "straight" temple. The former are to be preferred in all cases where the glasses are to be worn constantly or nearly so, and the latter for

FIG. 7.



"X," "K," "CURL," AND "SADDLE" BRIDGES.

those who wear glasses for near work only, and require to remove them frequently from the eyes. Hook temples are made in three lengths, designated as short, medium, and long. These are sufficient for all cases.

Securing a proper fit in the bridge, upon which so much of the comfort and efficiency of spectacles depends, was a difficult matter until the ingenuity of Dr. Charles Hermon Thomas, of this city, suggested what is known as the "saddle bridge," which solved the problem. (See Fig. 7.) This bridge may be varied to suit every possible case, and

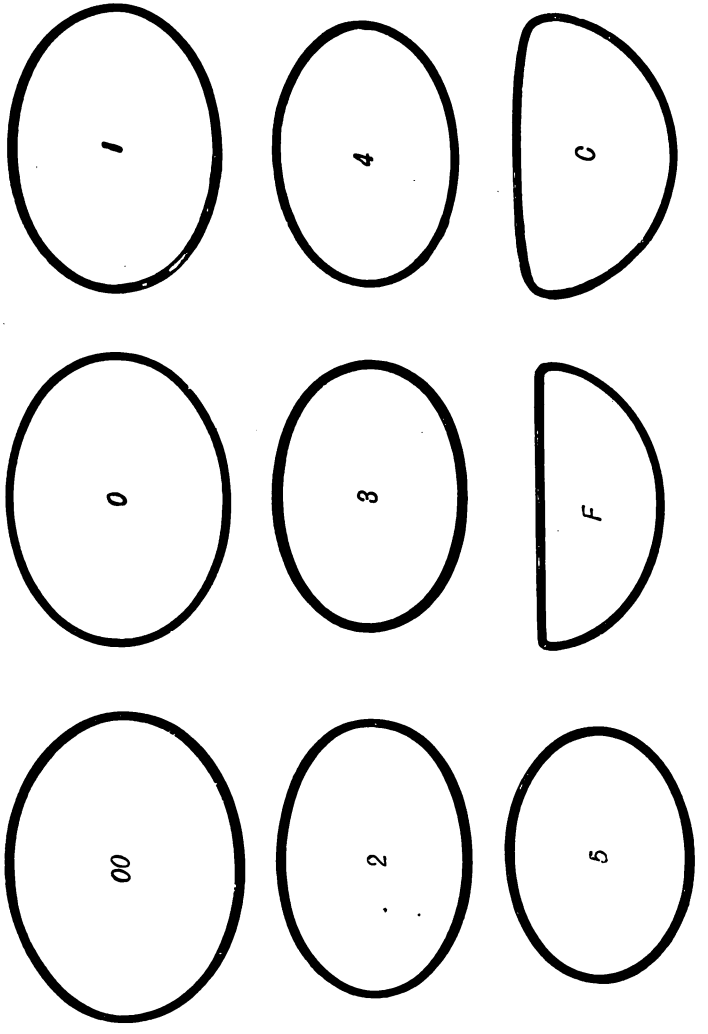
is always to be preferred. The "K" bridge, formed of wires in the shape of the letter K, is allowable in some cases. The nearly similar "X" bridge allows the glasses to teeter, or see-saw across the nose, with the motions of the head. It is, however, the best form of bridge for reversible glasses; that is, glasses for persons having sight in one eye only, who may have their distant glass set in one side of a frame and their near glass in the other. By using this bridge and straight temples, or hook temples without a shoulder at the hinge, the spectacles may be turned over so as to bring either lens before the wearer's seeing eye. The old-fashioned bridge, called the "curl," is unobjectionable for cases in which the bridge of the nose is prominent, or for the spectacles of old people, who like to slip their glasses down toward the end of the nose. None of the forms mentioned, however, has any advantage over the saddle bridge for any case. A small piece of cork is sometimes attached to the under side of the bridge where it comes in contact with the skin. It is unnecessary if the frames fit the face of the wearer properly. If it be desirable to remove all pressure from the bridge of the nose and transfer it to the sides, it is best done by soldering a pair of guards, similar to those used on eyeglasses, to the spectacle bridge.

The earliest spectacles appear to have had round eyes. Various other shapes are occasionally seen, as octagon, oblong, etc. The oval has about displaced these antiquated forms, and is made in sizes known to the trade in America as follows:

TABLE II—SIZES OF EYES.

No. 00. $1\frac{9}{32}$ by $1\frac{1}{4}$ in. or 41 by 32 mm. large coq. size.
" 0. $1\frac{7}{32}$ by $1\frac{3}{16}$ in. or 39 by 30 mm. coq.
" 1. $1\frac{7}{16}$ by $1\frac{1}{8}$ in. or 37 by 28 mm. standard large eye.
" 2. $1\frac{3}{32}$ by $\frac{31}{32}$ in. or 36 by 25 mm. standard F. G. size.
" 3. $1\frac{3}{8}$ by $1\frac{1}{32}$ in. or 35 by 26 mm. standard interchange.
" 4. $1\frac{1}{32}$ by $\frac{31}{32}$ in. or 34 by 25 mm. standard small eye.
" 5. $1\frac{1}{4}$ by $\frac{29}{32}$ in. or 32 by 23 mm. children's size.

FIG. 8.

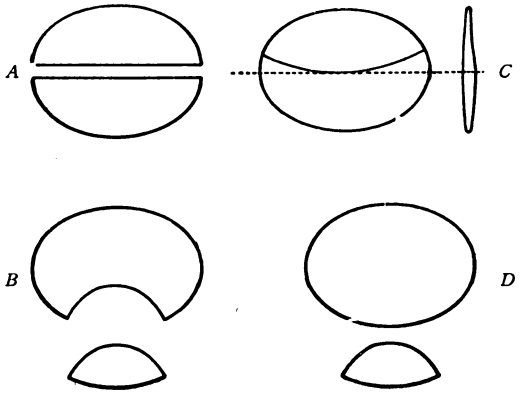


OVALS SHOWING THE ACTUAL SIZE OF EYES ACCORDING TO TABLE II.

Where glasses are used for near work only, the eyes are sometimes made of semi-oval shape, allowing the line of sight to pass over their upper, straight edge when the wearer views a distant object. These are known as "half," "pulpit," or "clerical" eyes, and are very convenient, especially to public speakers, as their name implies. They do not seem to me as well known or as generally used as they should be.

Bifocal Glasses.—When glasses of different focusing power are required for distant and near vision, the trouble

FIG. 9.



incident to frequent changing is obviated by "bifocal" glasses. That is, the lower part of the spectacle eye, which is used for near work, is made to differ in focusing power from the upper part, which is used for distant vision. Such bifocal glasses are also called Franklin glasses, from the philosopher who, as we have seen, invented them.

The object sought may be attained in various ways. In the early Franklin glasses each eye contained two half-oval pieces, with their straight edges in apposition (*A*, Fig. 9). This has been improved upon by making the line of junc-

tion a curved one, giving somewhat greater latitude of distant vision and rendering the glass more secure in its frame. The most modern and successful form of bifocal glasses is figured at *D*, Fig. 9. They are called "cemented" bifocals. To the back or front surface of the distance glass is cemented, by means of Canada balsam, a small lens whose strength, added to that of the distance glass, equals the glass required for near work. The upper edge of the supplemental lens should be ground as thin as possible in order to render it inconspicuous. A special grade of these lenses is made by a patented process by which the supplemental lens is ground very thin by fastening it to a block of glass instead of one of iron, and grinding the two pieces of glass away together. These spectacles are strong, light and handsome, and may readily be made in the frameless form like those represented in Fig. 6. For cylindrical lenses this arrangement is, moreover, cheaper than the others, since only the distance glass need have the cylinder ground upon it, the supplemental segment being a simple sphere. The changes in the correction for near which are likely to be needed from time to time are readily and cheaply effected in this form of bifocal glass.

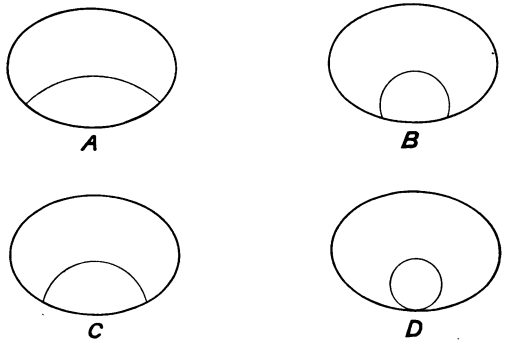
The shape and size of the supplemental segment may be varied to suit all exigencies of use or taste. Fig. 10 illustrates some of the more common forms, of which *B* and *C* are the most useful.

In still another form of bifocal glass the small supplemental lens figured at *D* is countersunk, that is to say, is cemented into a corresponding concavity ground in the distance glass. Or the distance glass may be composed of two full-sized plano-convex lenses with their plane surfaces in apposition, each of these surfaces being ground out at its lower part, so as to house the small supplemental lens between them. These two forms admit of a reduction of weight and the abolition of chromatic aberration in the

heavy glasses required in aphakia. To accomplish the latter purpose the distance lens is made of crown glass and the supplemental lens of flint glass. In this form they are called achromatic bifocals. Their disadvantage lies in the expense of their manufacture.

Fused bifocals are a variant of the countersunk supplemental lens. In their manufacture a small lens of flint glass is let into a large lens of crown glass by countersinking, as described above. Instead of cementing the supplemental lens in position, however, the lenses are heated

FIG. 10.

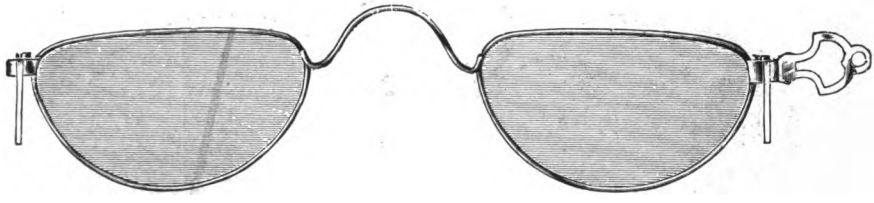


to the point of fusion of the glass, when its two portions unite. The surfaces of the glass are then reground. One surface of the small supplemental lens is exposed to the grinding and is reduced to the same curvature as the corresponding surface of the main lens. The necessary difference in the refraction of the upper and lower portions is dependent on the difference in index of refraction of the crown glass of which the main lens is composed and the flint glass of the supplemental lens.

Another improved form of bifocal glass is made in one piece by a special method of grinding which produces two different spherical surfaces on one side of the

lens. This is an old idea, and the old form of the glass is shown at *C*, Fig. 9. This old glass is very faulty from a prismatic effect inherent in the method of manufacture, and never came into general use. The modern glass is made strongly concavo-convex, the posterior surface being — 6. D. The lower portion of the surface, however, is ground on a separate tool to some less degree of concavity. The posterior surface becomes, therefore, bifocal. The anterior surface is given any required convexity. For instance, if the posterior surface is ground — 6. D., with its lower portion — 4. D., and the anterior surface is made + 7. D., the result will be a bifocal glass whose upper portion will be

FIG. 11.

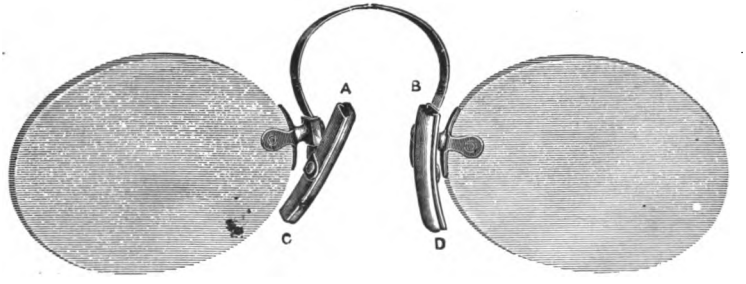


+ 1. D. and the lower portion + 3. D. Where a cylindrical element is required in this glass the anterior surface is given the toric form. The fused bifocal and this ground bifocal resemble each other quite closely in appearance. They contain no cement and the line between the two portions is quite inconspicuous. In point of efficiency and cost there is not much choice between them. In point of comfort and use to the wearer they have not any very great superiority over the cemented form costing approximately half as much and in which the near segments may be changed at slight expense.

All bifocals have the inconvenience that in walking, the floor just in front of the patient's feet is not seen clearly because viewed through the near glass. Spectacles which

revolve on the long axis of the "eye," bringing the distance glass to the lower portion of the frame, have been contrived to overcome this difficulty, but they are cumbersome and, moreover, it requires more effort to effect the revolution of the glass than it does to bend the neck sufficiently to bring the upper segment into the line of vision when the ordinary bifocals are worn. Some persons declare that they cannot become accustomed to bifocals however well adjusted. Parallel, horizontal lines, as those of a staircase, are particularly confusing, it being possible to see each line doubled if the junction of the two segments of the glass is placed just

FIG. 12.



opposite the pupil. Such persons may prefer having an "extra front" (Fig. 11): that is, a second pair of spectacles whose temples are replaced by short hooks, by means of which they are hung in front of the frame already upon the face. This is a rather clumsy device; less so, however, when the eyes of the extra front are made half oval instead of oval.

Eyeglasses.—The increased popularity of eyeglasses has stimulated invention and they now present a greater variety of forms than do spectacles. Every part is subject to such change and adjustment that it is quite possible to fit them to cases which were out of the question with th old forms. e

FIG. 13.

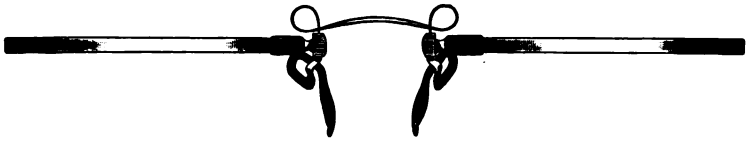
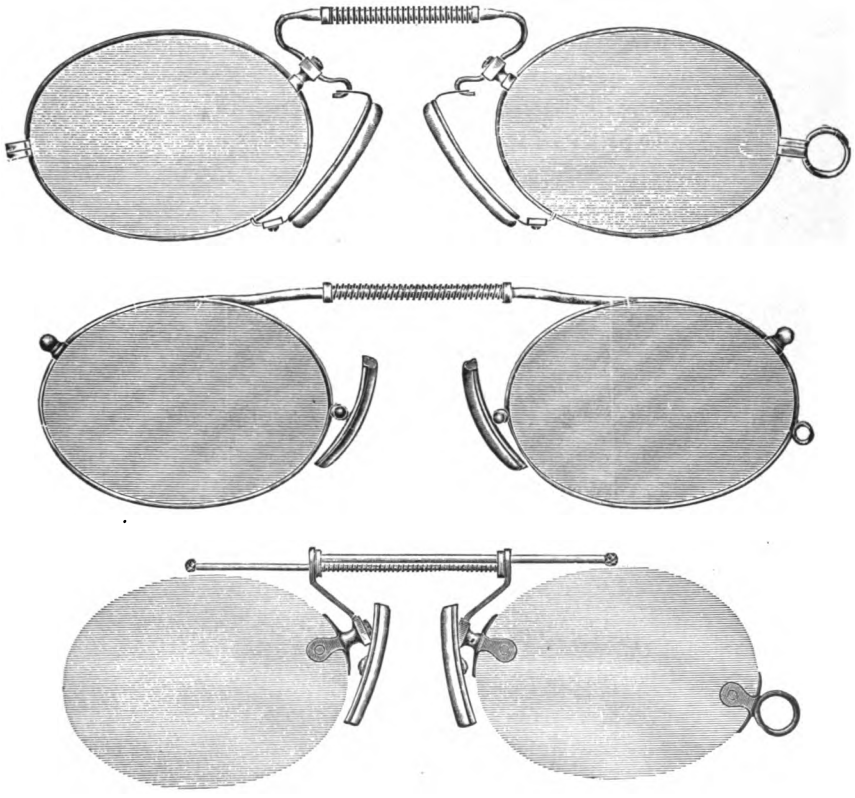


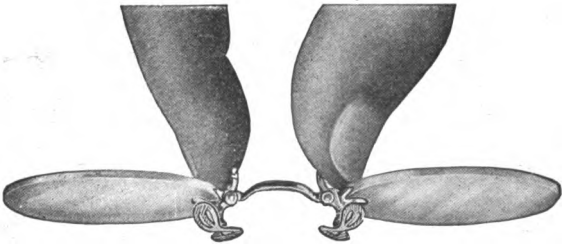
FIG. 14.



FORMS OF RIGID FRAME OR "BAR SPRING" EYEGLASSES.

An eyeglass is held in place by the pressure of a spring, or springs, upon the sides of the nose. There are four methods of placing this spring and hence four radically different forms of eyeglasses. First, we have the old and familiar form of arched spring (Fig. 12) which allows the frame to "open" while the lenses remain in their original plane. Second, the spring may be placed in a plane approximately at right angles to that of the lenses and the frame opens by the outer ends of the lenses moving forward. (Fig. 13.) Third, the lenses are joined by two bars sliding over each other in connection with a spiral spring. The frame opens when the two lenses are drawn apart along the line of their long axes. (Fig. 14.) Fourth, the lenses are joined by a rigid bridge, like a spectacle, while the nose-pieces are directly connected with spiral

FIG. 15.



springs which press them to the sides of the nose. To open the frame special levers for the thumb and finger are provided by means of which the nose-pieces are pressed apart. (Fig. 15.) In another variety these levers are operated by pressing forward the outer ends of the lenses.

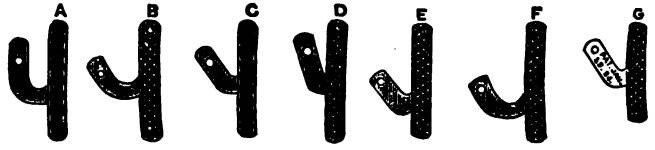
The first of these forms still holds its place as the most generally useful. It is simple and inconspicuous and the spring acts directly. For the majority of cases it is to be preferred. Its spring may be made light or heavy and may be offset from the plane of the lenses to accommodate over-

hanging brows. The second form offers no marked superiority over the first, from which it differs only in the direction of the action of the spring. This may make its hold more certain in a few cases, and occasionally persons who have tried both will prefer this form. The third and fourth forms have the same object in view, namely, to hold the lenses in position with the certainty of a spectacle frame, allowing none of that displacement of the axis of a cylinder, or base of a prism which is possible when they are joined by a yielding spring. The form designated in this description as "third," and which is usually called the "bar-spring" eyeglass and of which there are several variations (Fig. 14) has not met with much favor. They are heavy and cumbersome looking and there is apt to be lost motion between their sliding bars, which allows the displacement they are intended to prevent. The last of our four forms has more merit. Here, the junction between the lenses is really rigid, and no alteration of their relation to each other can take place. It is possible, however, for one lens to be displaced upward and the other downward, or for one to stand forward and the other backward. This frame contains two springs, instead of one as in the other forms, and weakening of one spring may cause one of these displacements. Moreover, the small spiral springs are not very durable. In spite of its limitations, however, this frame has distinct value in some cases, especially where the lenses are heavy.

Nose-pieces are furnished in many forms. The use of the old form (Fig. 2) which lies in the same plane as the lenses, is now quite limited. The "offset guard," which bears upon the nose posterior to the plane of the lenses is much more generally useful. The latter should certainly be preferred for any case in which the glasses are to be worn for more than a few minutes at a time. There are dozens of varieties of the offset guard, many of which exist only

for trade purposes and are advertised much beyond any peculiar merit which they possess. Usually, the fewer and simpler the parts of any implement the better. The best guard is one stamped from a single piece of metal. Rivets will frequently loosen or fall out, or the metal may split to a rivet hole. As for pivots in nose-pieces, they are a delusion. What we should seek is not a self-adjusting eyeglass, but one capable of wide adjustment, and which will keep the shape which we give it. To this end the metal should be tough and pliable, though possessed of a certain amount of rigidity. The bearing surfaces of

FIG. 16.



VARIOUS PATTERNS OF THE OFFSET GUARD.

"A." For shallow bridge, prominent eyes, flat forehead.
"B." For shallow bridge, prominent eyes and forehead.
"C." The guard used for the average case.
"D." Deep-set eyes, prominent nose and forehead.
"E." Same as "C," but for lowering glasses (for reading).
"F." Same as "B," but for lowering glasses (for reading).
"G." Same as "C," but somewhat smaller and neater, although having less bearing surface.

nose-pieces may be covered with cork, shell or celluloid. They soon become greasy and slippery, and beside being thick and clumsy, are not durable. If one tries to mold such nose-pieces to a different shape, the cork or shell frequently breaks, or the rivets pull out. The later patterns are stamped from a single sheet of metal, without any covering for the bearing surfaces, which are corrugated, fenestrated, or divided into two or more portions to give

a more clinging hold upon the skin. In adjusting these nose-pieces to the patient's face they may be shaped with the pliers with much greater freedom than can the other forms.

The "arm" or "foot" of the nose-piece is, in most forms, made in several lengths and shapes, for use on variously proportioned faces (Fig. 16). Much of the adjusting of eyeglasses is done by bending and twisting this arm.

Studs of eyeglasses are made in about six different lengths, from 1 mm. to 6 mm. By means of these the intercentral distance of the lenses may be varied. In each of these lengths an offset stud is made, which may be used to place the lenses farther forward. Moreover, there are angular forms useful in tilting the lenses.

Spectacles for Cosmetic Effect.—Something may legitimately be done, at times, in the way of improving the appearance of a patient by the application of glasses. The blind whose eyes are not only sightless, but unsightly, very commonly hide them behind colored glasses. Neatly fitting spectacles with large eyes of ground glass render the appearance of such persons less lugubrious. When one eye is useless for vision, and at the same time small, and the orbit undeveloped, a gratifying improvement in the appearance of the patient may be attained by placing before the shrunken eye a convex glass of sufficient strength to magnify it to the size of its fellow. The condition known as epicanthus can generally be removed by wearing eyeglasses whose nose-pieces draw just enough on the inner canthi to smooth out the offending fold of skin. As the subjects of epicanthus are generally flat-nosed, it may be necessary to furnish the eyeglasses with a pair of hook temples to keep them in place. Since operations for this disfigurement are so unsatisfactory, such an appliance is probably the best treatment we can advise in case the trouble is not outgrown.

II. THE PRINCIPLES OF SPECTACLE FITTING.

WE have now to consider the essential principles of placing glasses before the eyes. The usefulness of spectacles depends almost as much upon the fidelity with which these principles are carried out as it does upon a careful correction of the errors of refraction.

Centering and Decentering.—By the visual axis, or, in English, the line of sight, is meant a line from the yellow spot of the retina through the nodal point of the eye to the object sighted.

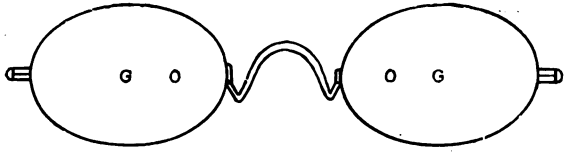
By the principal axis of a lens we mean a line passing through the optical center of the lens (the thickest part, if the lens is convex; the thinnest if concave) at right angles to its surfaces.

The geometrical center of a spectacle glass may be shortly said to be that point on its surface which is equally distant from the extremities of the figure to which it is cut. The principal axis of the lens may or may not pass through this latter center.

We habitually regard as the normal position for glasses one in which, when the eyes are looking at a distant object, the visual axes correspond exactly in position with the principal axes of the lenses, and together they pass through the geometrical centers of the spectacles. In other words, the geometrical center of the spectacle eye and the optical center of the spectacle lens coincide, and the center of the pupil for each eye lies directly behind them. Regarding decentering, some confusion is apt to arise because the word is used in two different connections.

If the visual axis pass to the temporal side of the optical center of a glass held before an eye, then, with respect to that eye, the glass is said to be "decentered in." If the visual axis pass to the nasal side of the optical center of the glass, the latter is "decentered out." Similarly a glass may be decentered in any other direction. When speaking of spectacles, however, without reference to the eyes of the wearer, they are said to be "decentered in" when their optical centers lie to the inner side of their geometrical centers; "decentered out" when the optical centers are to the external side of the geometrical centers, etc. A

FIG. 17.



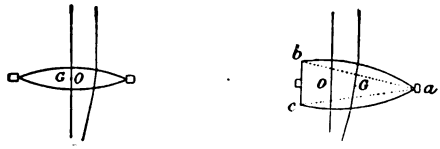
SPECTACLES WITH LENS DECENTERED IN.
G G show the position of the geometrical centers; O O, that of the optical centers.

glance at Fig. 17, which represents a pair of spectacles decentered in, will make clear what is meant.

From the above it will readily be seen that when it is desired that a patient wear decentered lenses, the effect may be obtained in either of the two ways; first, by decentering the lenses in their frame; second, by displacing them, together with their frames, from what I have described as the normal position. The first method has the disadvantage of increasing the weight of the glass, while the second limits the field of binocular vision. In practice, the second method should be employed to the greatest extent possible without unduly interfering with binocular vision for the distance at which the spectacles will be used, and, should still farther decentering be required, the method first mentioned should be brought

into service. For instance, suppose we wish to order glasses with each lens decentered in 8 mm. This would mean that the optical centers are to be 16 mm. nearer together than the patient's pupils. Let us suppose that by a careful consideration of the distance for which the glasses are prescribed, of the distance at which they must be placed in front of the eyes, and of the size of the spectacle eye used, we find that the frame can only be made 10 mm. narrower than normal without the outer rims of the "eyes" becoming annoying. This leaves 6 mm. to be obtained by decentering the glasses in their eye wires. If the distance between the patient's pupils were 60 mm., we would order the distance between the geometrical centers of the spectacle eyes to be 50 mm., and each eye to be decentered in 3 mm.

FIG. 18. FIG. 19.



SHOWING THE PRISMATIC EFFECT OF DECENTERING.

The optical center, O, in Fig. 18 coincides with the geometrical center, G. In Fig. 19, which represents a decentered lens of the same spherical curvature, O has been removed toward the base of the virtual prism *b a c*. (*After Maddox.*)

Prismatic Effect of Decentering.—It is to obtain a prismatic effect from spherical lenses that decentering is generally ordered, since a decentered lens is identical with a lens of the same strength combined with a prism. This is graphically shown by Figs. 18 and 19, the latter of which represents a section of a decentered lens, which will readily be seen to be precisely the same as the result would be if the normally centered lens shown in Fig. 18 were split into halves and the prism *b a c* introduced between them.

The size of the glass disk from which spectacle lenses are

ground will not allow of more than about 2 mm. of lateral decentering for a No. 1 eye; 3 mm. for Nos. 2 and 3; and 4 mm. for No. 4. Vertically, they may be decentered much more. When ordered to decenter laterally more than this, or to furnish a prismatic effect greater than can be obtained by this much decentering, the optician first manufactures a prism of the requisite strength, and then grinds spherical surfaces upon its two faces. It is, therefore, of not much importance whether, in ordering a sphero-prismatic combination, we express the prismatic element in degrees of the refracting angle, or in millimeters of decentration of the lens: the optician produces the glass by whichever method is the more convenient.

The stronger the lens, the less decentering it requires to produce a given prismatic effect, and where the combination desired is that of a strong lens with a weak prism, the more accurate practice probably is to order the lens decentered the requisite number of millimeters. For this purpose a table of equivalents, such as is given below, is necessary. To use it we find in the first column the strength of the lens used, and on a level with this, in the column at whose head stands the strength of the prism required, is given in millimeters the amount of decentration necessary.

It is one of the beauties of the reformed numbering of prisms (see page 16), that by a simple calculation one can tell in a moment the amount of decentration required to produce any required number of centrads, by means of any given lens.

Divide the number of centrads required by the strength of the lens, in diopters. The quotient is the necessary decentration, *in centimeters*. For example: to produce a prismatic effect of 3. Cr. by means of a lens of 5. D., it is necessary to decenter as many centimeters as 5 is contained times in 3, which is .6 centimeters.

TABLE III.*—DECENTERING EQUIVALENT TO A GIVEN REFRACTING ANGLE (INDEX OF REFRACTION, 1.54).

Lens	1°	2°	3°	4°	5°	6°	8°	10°
1 D,	9.4	18.8	28.3	37.7	47.2	56.5	75.8	95.2
2	4.7	9.4	14.1	18.8	23.6	28.2	37.9	47.6
3	3.1	6.3	9.4	12.6	15.7	18.8	25.3	31.7
4	2.3	4.7	7.1	9.4	11.8	14.1	18.9	23.8
5	1.9	3.8	5.7	7.5	9.4	11.3	15.2	19
6	1.6	3.1	4.7	6.3	7.9	9.4	12.6	15.9
7	1.3	2.7	4	5.4	6.7	8.1	10.8	13.5
8	1.2	2.3	3.5	4.7	5.9	7.1	9.5	11.9
9	1	2.1	3.1	4.2	5.2	6.3	8.4	10.5
10	.9	1.9	2.8	3.8	4.7	5.6	7.6	9.5
11	.9	1.7	2.6	3.5	4.3	5.1	6.9	8.7
12	.8	1.6	2.4	3.1	3.9	4.7	6.3	7.9
13	.7	1.4	2.2	2.9	3.6	4.3	5.8	7.3
14	.7	1.3	2	2.7	3.4	4	5.4	6.8
15	.6	1.3	1.9	2.5	3.1	3.8	5.1	6.3
16	.6	1.2	1.8	2.4	3	3.5	4.7	6
17	.6	1.1	1.7	2.2	2.8	3.4	4.5	5.6
18	.5	1	1.6	2.1	2.6	3.1	4.2	5.3
19	.5	1	1.5	2	2.5	3	4	5
20	.5	.9	1.4	1.9	2.4	2.8	3.8	4.8

Table IV is constructed by applying this rule. In it, however, the distances which the lenses must be decentered have been reduced to millimeters by moving the decimal point one place to the right, in order to make it practically more convenient, and render it homologous to Table III, like which it is used.

A cylindrical lens, or the cylindrical element of a spherocylindrical lens, when decentered in a direction vertical to its axis, acts as a spherical lens of the same strength. Thus, a + 2. Sph. ⌓ + 1. Cyl. axis vertical, decentered horizontally, would have the same prismatic effect as a + 3. Sph. treated in the same way. As the axis is inclined toward the direction of decentration, the prismatic effect of

*Jackson: "Transactions of the American Ophthalmological Society." 1889.

the cylinder diminishes, and disappears when they coincide. Thus, a + 2. Sph. ⊂ + 1. Cyl. axis horizontal, decentered horizontally, would have merely the prismatic effect of a + 2. Sph. so treated.

TABLE IV.—DECENTERING EQUIVALENT TO A GIVEN NUMBER OF CENTRADS.

Lens	1 Cr.	2 Cr.	3 Cr.	4 Cr.	5 Cr.	6 Cr.	8 Cr.	10 Cr.
1 D,	10	20	30	40	50	60	80	100
2	5	10	15	20	25	30	40	50
3	3.3	6.6	10	13.3	16.6	20	26.6	33.3
4	2.5	5	7.5	10	12.2	15	20	25
5	2	4	6	8	10	12	16	20
6	1.6	3.3	5	6.6	8.3	10	13.3	16.6
7	1.4	2.8	4.2	5.7	7.1	8.2	11.4	14.2
8	1.2	2.5	3.7	5	6.2	7.5	10	12.5
9	1.1	2.2	3.3	4.4	5.5	6.6	8.8	11.1
10	1	2	3	4	5	6	8	10
11	.9	1.9	2.8	3.7	4.6	5.5	7.3	9
12	.8	1.8	2.5	3.3	4.1	5.	6.6	8.3
13	.7	1.5	2.3	3	3.8	4.6	6.1	7.6
14	.7	1.4	2.1	2.8	3.5	4.2	5.7	7.1
15	.6	1.3	2	2.6	3.3	4	5.3	6.6
16	.6	1.2	1.8	2.3	3.1	3.7	5	6.2
17	.5	1.1	1.7	2.3	2.9	3.5	4.7	5.8
18	.5	1.1	1.6	2.2	2.7	3.3	4.4	5.5
19	.5	1	1.5	2.1	2.6	3.1	4.2	5.2
20	.5	1	1.5	2	2.5	3	4	5

Normal Lateral Centering.—In proportion as the prismatic effect of decentered lenses is a valuable property where this effect is desired, it has to be guarded against in those cases which do not require it, to which number belong, of course, the great majority of the cases we are called upon to treat. If the objects looked at through spectacles were always situated in the same direction and at the same distance, fixing the position proper for the centers would be a simple matter; but, in the movements

of the eyes, each pupil roves over a territory some 18 mm. ($\frac{3}{4}$ in.) long by 15 mm. broad. When the eyes are directed toward a distant object the centers of the pupils are about 60 mm. apart, and on convergence only 56 mm., so that the proper adjustment of spectacles is a series of compromises between that proper for the position of the eyes in which the glasses will be most used and other positions in which they will be less used. Of course, the position in which they will be most used must receive the greatest consideration.

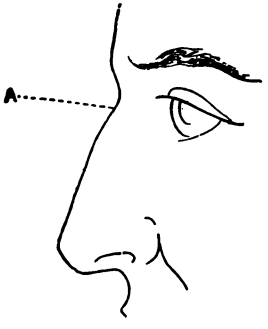
The proper position for the centers of "distance" glasses has already been stated. When glasses are to be used for near work only, they should be decentered "in" two or three millimeters on each side from this "normal" position, as such glasses, being never used in that position, but only when the visual axes are converged, would otherwise never be rightly centered. What amounts to the same thing, and is more often done, is to make the front of the near spectacles four or six millimeters narrower than if they were intended for distant vision: four millimeters narrower for a working point of 15 inches; six millimeters narrower for one of 10 inches. Concerning the centering of glasses which are worn constantly, no rule for all cases can be laid down, since accurately centering for any one distance is decentering for every other. Fortunately, as a glance at Table III will show, it is only with lenses of high power that a considerable amount of prismatic effect is developed by slight decentering. Where such glasses must be worn constantly by a person who spends several hours daily at near work, they should certainly be slightly decentered inward.

The distance between the geometrical centers is regulated by the size of the spectacle eyes and the width of the space between them occupied by the bridge. Where the interpupillary distance is short, as in children, opticians are apt

to make the eyes of the spectacles so small as to interfere seriously with the field of vision through them. With the saddle-bridge there is no difficulty in diminishing the space between the spectacle eyes without interfering with the form of that part of the bridge which is applied to the nose, and the required adjustment should be made in this way, leaving the spectacle eyes of good size.

Normal Vertical Centering.—The glasses require, further, to be so placed that the points where the wearer's visual axes penetrate them shall neither be above nor below

FIG. 20.



the centers. This adjustment is readily seen to depend upon the relative height of the bridge of the spectacles and the bridge of the nose at the point where the spectacles rest. The higher the spectacle bridge, the lower will the glasses stand upon the patient's face, and vice versa.

On the bridge of nearly every nose there may be felt a point at which the narrow, upper portion of the nasal bones gives place rather suddenly to the broader lower portion. Just here, in what has been called the "natural" position (A, Fig. 20), the bridge of the spectacles tends to rest, and the attempt to make it remain at any other point will not be very successful. In distance spectacles, then, the bridge

should be made of such height that when resting at this natural position, the centers of the spectacle eyes are at the same height as the centers of the pupils when the patient looks straight forward. When the glasses are to be used for near work only, their bridge should be made about 2 mm., or $\frac{1}{8}$ inch, higher than otherwise, allowing the centers to drop that much lower, as the wearer's eyes will nearly always be directed to objects below their own level.

Distance of the Glasses from the Eyes.—As a rule, the glasses should be placed just far enough from the eyes to escape the lashes in the act of winking. If the lashes touch the glass the latter quickly becomes soiled, and to the

FIG. 21.

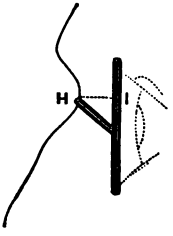
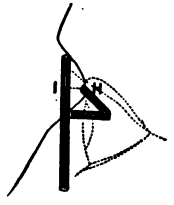


FIG. 22.



spectacles is, moreover, attributed any falling out of the lashes which may occur. Some persons, however, with myopia of high degree, prefer the glasses to be placed as close to the eyes as possible, regardless of the lashes, because of the larger clear images which they thus obtain. This adjustment of the glasses depends upon the relation of the top of the spectacle bridge to the plane of the glasses. Where the eyes are deep set, or the nose of the aquiline type, the top of the spectacle bridge must be in front of the plane of the glasses, or, as it is shortly called, "out". (Fig. 21). When the bridge of the nose is low and the eyes relatively prominent, as in the negro, Chinese, and children, the top of the bridge must be back of the plane of the glasses, or "in," as represented in Fig. 22.

Perpendicularity of the Plane of the Lenses to the Visual Axis.—A very important requirement, and one not sufficiently regarded in the fitting of frames, is that the plane of the correcting lens when in use shall be as nearly as possible perpendicular to the visual axis. The stronger the lens the more important is this detail, whose warrant lies in the fact that the refractive value of a given lens placed obliquely to the visual axis is no longer that indicated by its number, but is that of some other, stronger lens. A cylindrical lens so placed acts simply as a stronger cylindrical lens; a spherical lens, however, as a stronger spherical lens combined with a cylindrical lens with its axis at right angles to that about which the lens is rotated.

The results of the investigations of himself and others, of the effect of the obliquity of a lens to an incident pencil of rays, was summarized by Dr. Edward Jackson in a paper read before the American Medical Association in 1877, and their practical application to this part of our subject pointed out. From that communication the following table is extracted. It gives in the first column the degrees of obliquity at intervals of 5° up to 45°. In the second column is shown the refractive value of a 1. D. cylindrical, in the third that of a 1. D. spherical lens so inclined.

TABLE V.

Obliquity of the Lens.	Refractive Power of a 1. D. Cylindrical Lens so Placed.	Sphero-Cylindrical Equivalent of a 1. D. Spherical Lens so Placed.
0°	1. D. cyl.	1. D. spherical.
5°	1.01 "	1.00 sph.⊂0.01 cyl.
10°	1.04 "	1.01 sph.⊂0.03 cyl.
15°	1.10 "	1.02 sph.⊂0.08 cyl.
20°	1.17 "	1.04 sph.⊂0.13 cyl.
25°	1.30 "	1.06 sph.⊂0.24 cyl.
30°	1.44 "	1.09 sph.⊂0.36 cyl.
35°	1.69 "	1.12 sph.⊂0.56 cyl.
40°	2.01 "	1.16 sph.⊂0.83 cyl.
45°	2.46 "	1.22 sph.⊂1.24 cyl.

FIG. 23.

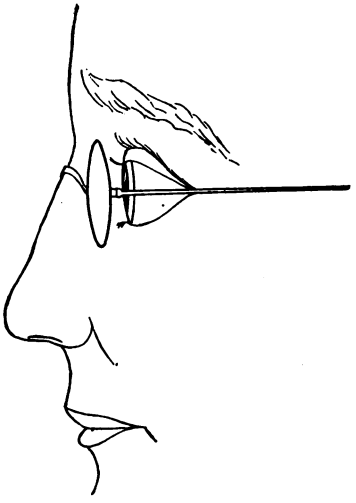
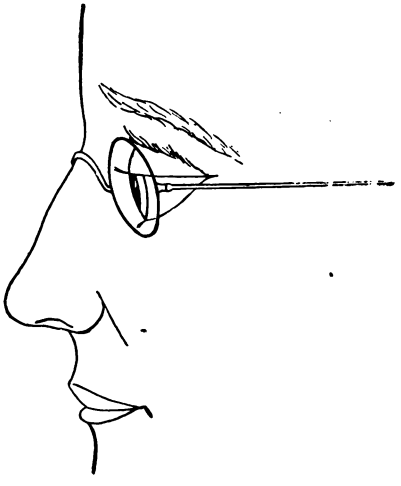
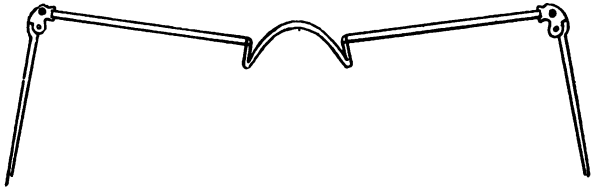


FIG. 24.



To fulfil this requirement of perpendicularity to the visual axis, the lenses of spectacles used only for distance should lie in a vertical plane; that is, they should face directly forward, as shown in Fig. 23. Since the visual axes are directed downward and forward when near work is done below the level of the eyes, glasses for near must face downward and forward, as in Fig. 24, in order that the plane in which they lie shall be perpendicular to those axes. Furthermore, in viewing near objects the visual axes are directed inward and toward each other. This will require the glasses to face inward also, as represented in Fig. 25, so that they come to lie in different planes, instead of in the same plane, as formerly.

FIG. 25.



When "constant" glasses are prescribed, the lenses should be placed midway between the proper facing for near and that for distance glasses. Then, though the lens is not exactly properly inclined either for distant vision or near work, the result of such slight obliquity to the visual axis is unimportant, since, as a reference to Table V will show, it is only in the higher degrees of obliquity that the increase in power, and especially the development of cylindrical effect from spherical lenses, is rapid. Moreover, by slightly bending the neck a moderate degree of obliquity of the glasses to the visual axis may be removed without discomfort to the wearer.

The position of bifocal glasses should also be between that proper for near and for distance glasses, but nearer

that of the stronger glass. This will generally be the near glass, as convex bifocals are much more frequently prescribed than concaves, and such glasses should face only a little less downward than glasses intended entirely for near work. When concave bifocals are worn, however, they should face more forward and much less downward.

The angle which the plane of the glasses makes with the plane of the wearer's face depends entirely upon the angle formed by the plane of the glasses and the temples of their containing frames. Thus, when the temples are perpendicular to the plane of the glasses, as in Fig. 23, the latter will face forward and not at all downward. They may be made to face downward to any required degree by simply turning down the temples at the points where they are hinged to the end pieces. These must be equally turned down, however, as where only one is turned down, or one more so than its fellow, the result is not to make the glasses face downward, but to make the glass on the side of the lower temple ride higher on the face than its fellow.

Periscopic Glasses.—In the effort to further apply the law requiring that the plane of the lenses shall be perpendicular to the visual axes, we are met with the fact that with biconvex and biconcave lenses this relation is only strictly possible within a comparatively limited area surrounding the optical center of the lens. When the wearer looks through the periphery of his glasses the visual axes will pierce the lenses obliquely, and the refractive value of the latter will, of course, be governed by all the laws of tilted lenses. For instance, when the wearer of an ordinary convex lens looks through it near the edge, the optical effect of the glass before his eye is that of a stronger convex lens combined with a cylindrical lens; the axis of the latter depending on the part of the periphery pierced by the line of sight. In weak lenses, the slight inaccuracy of vision produced in this way is of small moment, but

where the strength of the lens used is greater than about 2. D. the patient's field of accurate vision is greatly reduced in size, and in viewing objects not directly in front of him he is obliged to perform wide motions of the head in order to be able to see them through the central portion of his glasses. This is especially true of cases of aphakia, where, of course, very strong lenses are generally necessary. To escape or lessen these disadvantages, strong spherical lenses should be, and generally are, made in the form of a meniscus, which when placed with its convex surface *from* the eye constitutes a periscopic glass. The ideal of this form of lens may be defined as a glass in which the center of curvature of one surface coincides with the center of rotation of the eye, and that of the other surface approaches it as closely as the required strength of the glass will permit. In such a glass the visual axis will always be perpendicular to the first surface, and nearly so to the second, at whatever point it pierces the glass, and in whatever direction the eye may be turned.

When a cylindrical or sphero-cylindrical lens is required, the best form of glass is the toric lens described on page 20. These lenses have, however, never been manufactured extensively, and the process of their manufacture, as well as the lens itself, being patented in this country, their cost is considerable. By transposing the usual formula, however, there may be obtained from any optician a sphero-cylindrical lens which approaches the periscopic form, and is certainly superior to one ground after the usual method. For illustration, if one desires to order + 2. D. Sph. ⊂ + .75 D. Cyl. Ax. 90°, the formula may be transposed and the order written for + 2.75 D. Sph. ⊂ — .75 D. Cyl. Ax. 180°. This glass, though optically of the same strength as the first, would have an approach to the periscopic form if placed with the cylindrical surface next the eye. The field of accurate vision would gain in all directions, espe-

cially in the vertical one, in which diameter, however, its enlargement is not of so much consequence as it is laterally. Aphakic eyes offer the best field of usefulness for this practice, as in them we have generally to deal with a high hyperopia, and often with hyperopic astigmatism requiring for its correction a convex cylinder with its axis horizontal. Let us suppose that after a cataract extraction we wished to order + 10. D. Sph. ⊂ + 6. D. Cyl. Ax. 180°. With this lens accurate vision would be limited to a vertical oval field situated directly in front of the patient, beyond the confines of which all objects would appear distorted by various cylindrical effects. We would, therefore, transpose the formula into + 16. D. Sph. ⊂ — 6. D. Cyl. Ax. 90°, and this glass will be likely to give the patient much more satisfaction than the other would have done, as with it he obtains a very good lateral field.

III. PRESCRIPTION OF FRAMES.

In order to prescribe the frames for a pair of spectacles, we must, after measuring the face or a frame which fits, record the dimensions of the frame we desire to order. The essential measurements are the intercentral distance, or width of front, and the three dimensions of the bridge. This list may be extended to include the measurement of the angle formed by the crest of the bridge and the plane of the lenses, that formed by the temples and the plane of the lenses, the distance between the temples an inch back of the glasses, and the distance from the hinge of the temples to the top of the wearer's ear. All these details are, however, so ready of adjustment, and the trouble and uncertainty of their prescription are so great, that in my judgment they are better left until the frame is received from the maker and we are ready to adapt it to the patient's face. The distance between the centers of the spectacle eyes is best obtained by measuring upon the face the distance between the centers of the pupils; the other dimensions of the frame, however, are more easily obtained by trying on a sample frame and taking the measurements from this, estimating any change which may be necessary. To do this requires a half dozen sample frames of different dimen-

Size of eye.	Between centers.	Height of bridge.	Top of bridge in or out.	Width of base.	Length of temple.
No. oo	66 mm.	8 mm.	1 mm. out	20 mm.	long (6½ in.)
o	64	6	2 "	24	medium (6 in.)
1	62	4	2 "	21	"
1	60	2	2 in	19	"
2	57	3	1 "	16	"
3	55	1	o	15	short (5½ in.)

sions in their different parts. With such an assortment as is here given, which is a very good one, a part nearly or exactly of the required size can always be found in one or

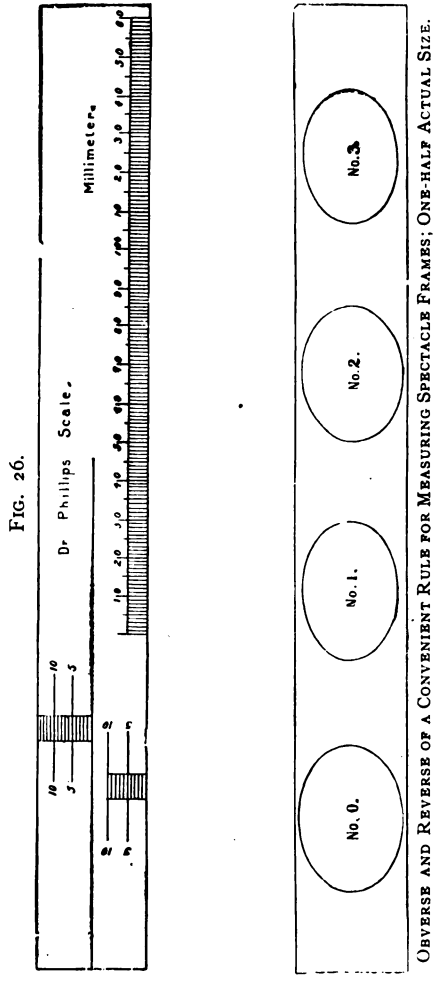


FIG. 26.

OBVERSE AND REVERSE OF A CONVENIENT RULE FOR MEASURING SPECTACLE FRAMES; ONE-HALF ACTUAL SIZE.

the other of the frames. It may, of course, be necessary to get the height of bridge from one frame, its breadth from another, and the length of temple from still a third.

A rule graduated in millimeters or sixteenths of an inch is also necessary.

I have had made for this purpose a rule which I think facilitates the work. As represented in Fig. 26, it has upon one side three scales graduated in millimeters and conveniently placed for taking the different dimensions of the frame, while on the reverse side are several ovals showing the principal sizes of spectacle eyes. Some of the uses of these scales are shown in Figs. 27, 28, 33, and 34; to avoid confusion one scale only is drawn in each diagram.

Philadelphia, ... 190

Name of Patient, ...

℞.

O. D. .....

O. S. .....

Unless otherwise specified, furnish the following: Medium length temples; saddle bridge; No. 2 eyes. Dimensions are given to middle of wires. Dimensions given are in millimeters.

Frames of $\frac{gold}{steel}$ *Catalogue No.* .....

Interpupillary Distance .....

Bridge { *Height* ..... *Top* $\frac{in}{out}$ .....
Width of Base .....

.....

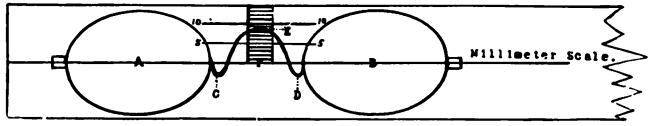
.....

M. D.

A prescription blank such as that here given indicates what measurements are required, and will be found useful in practice. The upper part is for the lenses, the lower part for the frames.

To Obtain the Interpupillary Distance, with which the first dimension of the frame, the distance between the geometrical centers (*A* to *B*, Fig. 27) is generally identical, the physician seats himself facing the patient in a good light, the latter being directed to look straight before him at some distant object. The measuring rule is placed before the patient's eyes, as close to them and as far from the physician's eyes as possible. The zero of the scale being

FIG. 27.

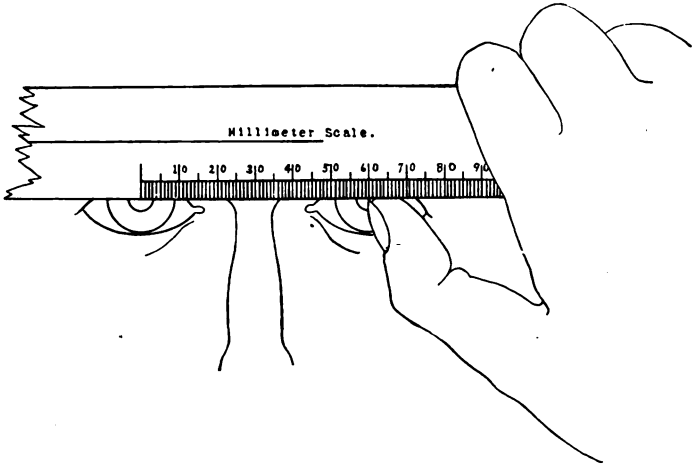


placed opposite the center of one pupil, the center of the other may be marked by the physician's thumb nail, as represented in Fig. 28, and the distance between them read off the scale. This distance seldom varies more than 5 mm. from 60 mm., or $2\frac{3}{8}$ in. It will be observed that as the physician's eyes are less than the length of his arm away from the patient's face when this measurement is taken, in fact, about two feet away, the marks upon the rule, though apparently opposite the pupils, will in reality be a little within the centers; so that the distance obtained will be a little less than it should be. When the physician's eyes are two feet away from those of the patient, and the rule is one inch away from them, the error in measuring an interpupillary distance of 60 mm. by this method is almost exactly 2 mm. This amount should, therefore, be added

to the apparent interpupillary distance to obtain the true one.

The measurement obtained in this way is sufficiently

FIG. 28.



accurate for most purposes, but if a greater degree of accuracy be desired in any case it may be attained by means

FIG. 92.

DR. MADDOX'S PUPIL LOCALIZER.

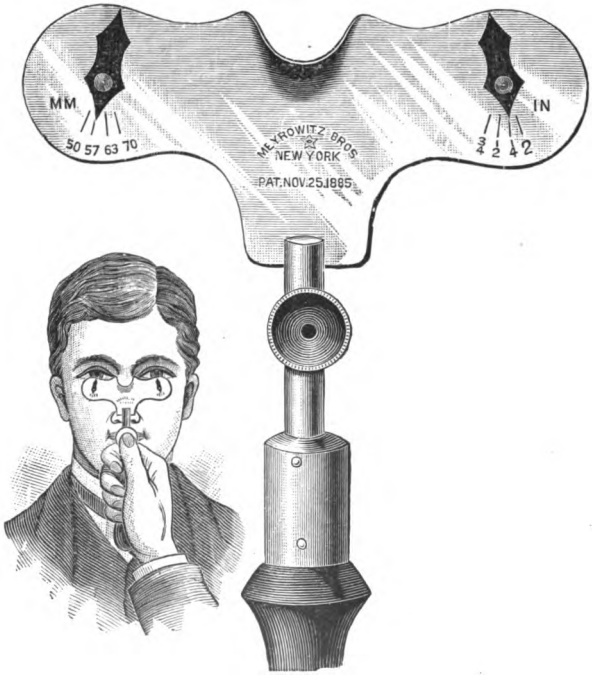
FIG. 30.

THE PUPIL LOCALIZER IN USE.

of the little device suggested by Dr. Maddox, which is represented in Fig. 29. This is to be placed before one of

the patient's eyes in an ordinary trial frame having a graduated bar for showing the distance of each geometrical center from the middle of the bridge. The gaze of the observed and that of the observing eye being directed to each other's pupils, the two sights of the implement are brought into line between them as shown in Fig. 30. The

FIG 31.

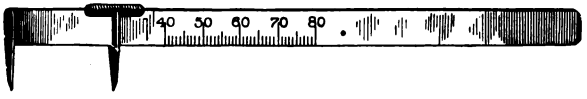


same procedure is then gone through with for the other eye, and the distance of the second pupil from the median line of the face, as registered by the trial frame is added to that of the first, to obtain the interpupillary distance. This procedure is also of advantage in revealing and measuring any difference in the distance of the pupils from the

median line, due to asymmetry of the face. The use of a trial frame for making accurate measurements requires the bestowal of considerable attention to see that the support of the nose-piece is vertical, the joints close and tight, and the markings correct; otherwise it may readily introduce the errors its use is intended to obviate. There are, in the shops, many special forms of the "pupillometer" constructed on the principle of a rule held before the eyes and a single sight for each pupil. Two of these are shown in Figs. 31 and 32. The interpupillary distance as registered by them requires, of course, the same correction as does that obtained by the simple graduated rule.

Height of the Bridge.—This is the distance of the top of the bridge above a line joining the centers of the lenses.

FIG. 32.

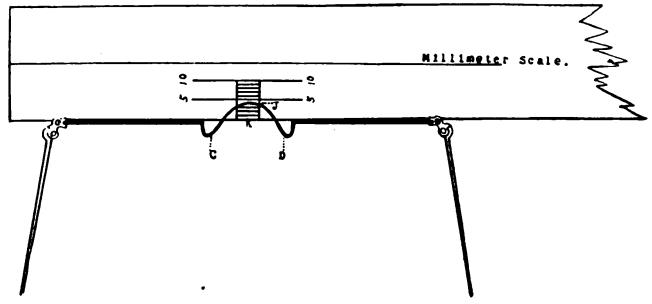


In Fig. 27, it is the distance from E to F, which is the height of E above a line joining A and B; not the height of E above a line joining C and D, which is sometimes erroneously supposed to represent the height of the bridge.

If a rule be held horizontally before the patient's eyes, with the lower edge touching the nose at the natural position for the spectacle bridge, the height of this edge of the rule above the pupil on either side will show at a glance about how high the top of the future bridge must be. We may then select from our sample frames that one whose bridge corresponds most nearly with this supposed height, and being sure to place it in the natural position, we carefully note whether the pupils are above or below the centers of the eyes of the frame. If they are below these centers, sufficient must be added to the height of the bridge

now upon the face to allow them to coincide; if the pupils are above the centers, a corresponding subtraction from the height of the trial bridge must be made. Each sample frame may have its dimensions attached to it, or any frame may be used as a fitting frame and afterward measured. To measure the height of a bridge the glasses are laid upon a sheet of ruled paper, or other object offering a convenient straight line, in such a way that the line passes through the geometrical centers of the eyes, or, what is the same thing, through the joints of the end pieces on each side (Fig. 27). The height to which the bridge projects above this line is then readily measured. It is seldom

FIG. 33.

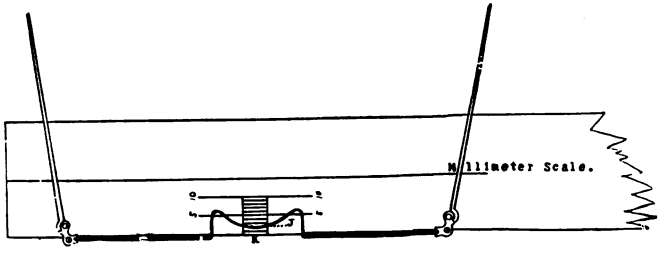


greater than 10 mm., and in rare cases may be a minus quantity, the top of the bridge being below the level of the centers of the lenses.

Relation of the Top of the Bridge to the Plane of the Lenses.—The measurement required to express this relation is that from *J* to *K* in Figs. 33 and 34; not the distance of *J* in front of a line joining *C* and *D*, as might be supposed. This measurement is also shown at *H I*, Figs. 21 and 22; it is obtained by a procedure similar to that just described for obtaining the height of the bridge. The rule being placed across the nose at the natural point,

and the patient requested to wink, it may readily be seen whether the lashes touch the edge of the rule. If they do, the top of the bridge of the future spectacles must be back of the plane of the glasses, or "in." If they do not, we note how much nearer, if any, the edge of the rule might be brought without their touching, and so obtain a guide to the distance the top of the bridge should be in front of the plane of the lenses, or "out." The fitting frame which comes nearest to the requirements of the case in this particular is then placed upon the face, when by viewing it from above or from the side it can quickly be seen just how much change, if any, is needed to place the glasses a little beyond the reach of the lashes. The method of measuring the distance of a bridge in or out is so plainly shown in

FIG. 34.



Figs. 33 and 34 that special explanation is unnecessary. They seldom measure more than 4 mm. out or 3 mm. in.

Width of Base.—The measurement from *C* to *D*, Fig. 33, is obtained, like the others, by measuring a bridge which fits, or estimating the change necessary in one which does not. This dimension is usually from 16 mm. to 20 mm.

Angle of the Crest of the Bridge.—It is not usually necessary to prescribe this angle, for the reason that the ine formed by the bones of the nose, as seen in the profile

of the face, is nearly always vertical at its upper portion and its direction changes so as to approach the horizontal as the nasal bones expand and jut forward to form the bridge of the nose. The direction of some portion of this line will coincide with the flat under surface of the top of the spectacle bridge, and it is on that portion of the line that the spectacles will tend to rest. There are cases, however, of noses with a very straight and vertical outline, in which the flat wire forming the top of the spectacle bridge finds no suitable support and rests, more or less, on its posterior edge. In other cases, exaggerations of the aquiline type, the line of the crest of the nose turns sharply forward to a nearly horizontal direction and the wire of the bridge tends to rest on its anterior edge. In these cases it is well to prescribe the angle which the top of the bridge makes with the plane of the lenses. Mr. Merry, of Kansas City, has invented a little implement for quickly determining this angle. Its appearance and the manner of its use are so well shown in Figs. 35 and 36 as to require no description.

This method of obtaining the dimensions of the bridge required may seem tedious and uncertain in the description; in use it is not so, and after trial I think will be found preferable to any special device so far invented for recording the measurements. These, after shifting of screws and bending of wires, leave one to estimate what changes are required just as might have been done without their aid. Moreover, the heavy parts and lost space in joints of trial frames may readily conceal an error of 2 mm., or even 3 mm. in some measurements; the large, round eyes with heavy rims will not go under the brows, so that the in-out measurement of the bridge must frequently be guessed at; and the relation of the upper part of the eye wires to the brows is not shown. In fact, they introduce, in my estimation, quite as many sources of error as they eliminate.

Where the face is unsymmetrical no exact rules of pro-

cedure can be given, and considerable ingenuity may be required to fit a frame to such a face. If the nose is very peculiar, or one side of its bridge markedly steeper than the other, it may be of advantage to take an outline of the bridge at the natural position by bending a piece of lead wire to fit accurately and marking the outline of this upon

FIG. 35.

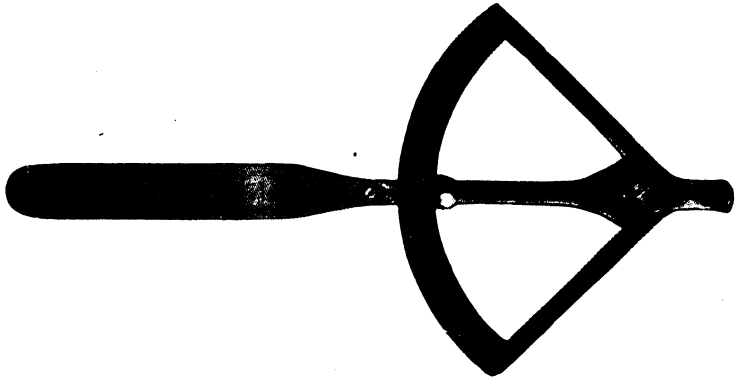
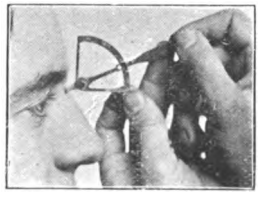


FIG. 36.



the prescription blank, or sending the wire itself to the spectacle maker. Sometimes the brows are overhanging and the eyes deep set; so that the glasses cannot be properly centered before the eyes and placed close to them without the upper part of the rims burying themselves in the brows. In such cases the glasses should be decentered upward in their frames and the bridge made sufficiently

high to bring the optical centers opposite the pupils. Though the patient will then look through the upper part of his glasses, his field of vision will not be any more limited than is already the case because of the overhanging brows.

Prescription of Eyeglasses.—The dimensions which it is usual to furnish in prescribing eyeglass frames are the interpupillary distance, of course, with the distance between the two upper and the two lower ends of the nose-pieces when they are in place on the face (*A* to *B*, and *C* to *D*, Fig. 12). These measurements alone will not insure a good fit in the frames, since neither the contour of the sides of the nose to which the guards are applied, the vertical centering of the lenses, nor the distance of the latter from the eyes are taken into account; but the same remark applies here as to the minor dimensions of spectacle frames, namely: that it is more simple, certain, and expeditious for the surgeon to make these adjustments in the frames themselves than to prescribe what the manufacturer shall do for him. A series of three or four frames with variations in the length and shape of the spring and in the pattern of the guards is sufficient for trying on. Fortunately, eyeglass frames admit of great variation by bending their different parts, and being put together with screws, these parts are quickly interchangeable. Almost the only thing about them which admits of no adjustment is the length of the spring, and it is well for one who prescribes many eyeglass frames to have a series of such springs at hand from which to replace one which may be found too long or too short.

IV. INSPECTION AND ADJUSTMENT OF SPECTACLES AND EYEGLASSES.

ORDINARY prudence demands that the prescriber of glasses make a careful examination of the manner in which his directions have been carried out, since neglect of this precaution may nullify the results of the most painstaking correction of the refraction. If the surgeon himself furnish the spectacles, it is doubly incumbent on him to make a thorough inspection of glass and frame, and to carefully adjust the latter so as to be entirely comfortable to the wearer. Then, too, it is not enough that the frames correctly perform their function at first; they must continue to do so. Should there be no optician in his neighborhood, the surgeon will be called upon to bring to a proper shape frames which have passed through all sorts of accidents, and it is better that he should do this work than entrust it to less competent hands.

Proving the Strength of Lenses.—The focal length of a convex lens may be directly measured by finding the distance at which it brings the sun's rays to a focus. To do this, the rays which have passed through the lens are simply caught upon a piece of paper or other screen, the two being held in such relationship that the image of the sun formed on the screen is round. The screen is then to be moved back and forth until the point is found at which this image is smallest, and the distance of such point from the lens is the focal length of the lens. To learn the strength of the lens in diopters, we divide 100 centimeters (one meter) by the focal length expressed in centimeters, or 40 inches (about one meter) by the focal length expressed

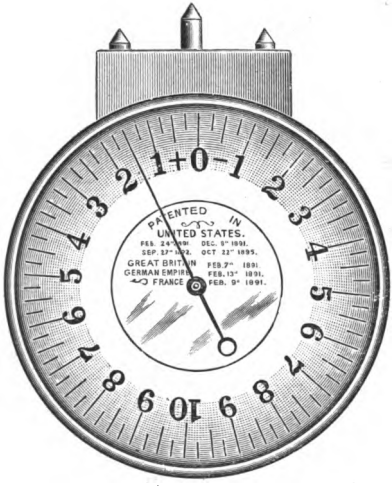
in inches. For instance, if we found the focus of the lens under examination to be distant 10 in., or 25 cm., from the lens, 40 in. divided by 10 in., or 100 cm. divided by 25 cm., will alike give a quotient of 4, and the lens measured was, therefore, a + 4. D.

The focal length of a concave lens may be similarly measured by combining it with a stronger convex lens and then measuring the strength of the resulting weaker convex. The strength of the original convex used being known, we have only to subtract from it the weak convex resultant to find the strength of the concave with which we are dealing. The focal length of convex and concave cylindrical lenses may be measured in the same way as the corresponding sphericals, it being only necessary to observe that the parallel rays of light after passing through a convex cylindrical lens are arranged in the form of a line at the focus of such lens; not brought to a point, as is the case with convex sphericals.

Phacometers.—Such methods as the one described above are, however, too tedious for ordinary use, though quite elaborate contrivances called phacometers have been devised on this principle. A lens measure constructed on an entirely different idea has appeared, the invention of Mr. J. T. Brayton, of Chicago. Fig. 37 shows the size and appearance of the instrument, as well as the method of its use. Of the three steel pins which project from its top the two outer ones are fixed, while the central one moves up and down easily but is held up by a spring. On pressing the surface of a spherical lens squarely against these points the central one will be depressed until they all three touch the glass, the curvature of the surface of the lens determining the amount of such depression. The motion being transferred through a rather simple mechanism to the hand upon the dial, this travels over a scale which shows in diopters the strength of the lens corre-

sponding to the surface tested. The other surface is then to be explored in the same way. If the lens is biconvex or biconcave, the results of measuring each surface separately are added together; if periscopic, the less is deducted from the greater. When used upon a cylindrical surface the hand will stand at zero when the three points are in line with the axis of the cylinder. When the points

FIG. 37.



are placed at right angles to the axis the strength of the cylinder is shown.

Since this instrument indicates the refractive value of a lens from the curvature of its surfaces only, leaving out of account the index of refraction of the material, it is evident that it can be accurate for only one variety of glass. As found in the shops it is adjusted for crown glass, and for lenses of this material it is quite accurate; while its convenience and low price as compared with other phacometers recommend it to favor.

Neutralization of Spherical Lenses.—The method of determining the strength of spectacles which is of most general utility is the well-known one of neutralization. If a convex spherical lens be held about a foot from the eye, and any object, say that part of a window frame where a vertical and horizontal line cross, be viewed through it, any motion given the lens will result in an apparent motion in the opposite direction of the object sighted. That is, if the lens is moved to the right, the object appears to move to the left; if the lens is raised the object appears to sink. If the same maneuver be employed with a concave spherical glass, the object again appears to move, but this time in the same direction as the motion imparted to the lens; if the lens is moved to the right, the object appears to move to the right also. Here we have the readiest possible means of distinguishing between a convex and a concave lens. Moreover, one gets in this way an idea of the strength of a lens, as the stronger the lens the more rapid is the apparent motion of the object seen through it.

If, continuing the experiment, the two lenses be placed together, with their curved surfaces in apposition, and a trial be made of the effect of moving them before an object, as was done previously with each lens singly, the object will appear: 1 (if the concave lens is the stronger), to move in the same direction as the motion of the glass, but more slowly than before; 2 (if the convex lens is the stronger), to move in the opposite direction to the motion of the glass, but more slowly than before; 3 (if the lenses are of equal strength), to have no motion. Therefore, to find the strength of a spherical lens it is only necessary to combine it in this way with successive lenses of known strength and of the opposite sign until that one is found which neutralizes the apparent motion of objects seen through it. This lens is the measure of the strength of the one tested. This method is accurate within an eighth diopter, or less, for

plano-convex and plano-concave lenses; with bi-convex and bi-concave glasses it is only possible to neutralize the apparent motion near the center of the lens; toward the edges motion will still be visible when the lenses are strong.

Cylindrical lenses may be recognized by viewing through them some object presenting a straight line, say the vertical line of a window sash. If the cylindrical lens be rotated about the visual axis, the portion of the vertical line seen through the glass will appear to be oblique, as compared with that seen above and below the glass (Fig. 38). This oblique displacement takes place in a direction contrary to

FIG. 38.

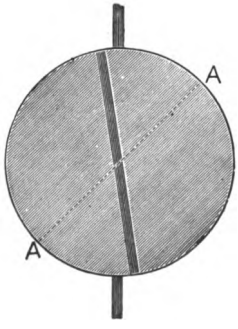
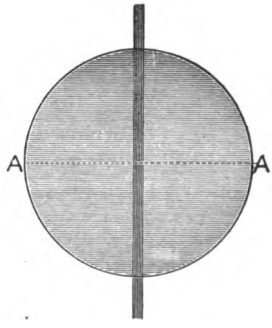


FIG. 39.



the rotary motion given the lens if the latter is convex, and in the same direction as the motion if the lens is concave. To ascertain the position of the axis of a cylindrical lens it should be rotated slowly in this manner until the line seen through it appears continuous with that above and below (Fig. 39). This line will then lie either in the axis or at right angles to it. To ascertain which of the latter is the case, the effect of motion from side to side is to be tried. If the axis of the cylinder corresponds with the vertical line looked at, motion from side to side produces apparent motion of the object; if, however, the axis lies at right

angles to the vertical line no such motion results. In other words, in the direction of its axis a cylindrical lens acts as a piece of plain glass; across its axis it acts as a spherical lens of the same strength. If it is desired to know upon which surface of a lens the cylinder is ground, this may be ascertained by holding the lens nearly horizontally between the eye and a window, so that the line of sight strikes its upper surface very obliquely. One can thereby see the lines of the window reflected upon the upper surface of the lens. By rotating the lens about its optic axis these lines appear broken if the surface is cylindrical, but retain their continuity if the reflecting surface is spherical. The direction of the axis of a cylindrical lens having been ascertained, its strength may be determined by neutralizing it with a cylinder of the opposite sign, as was explained when speaking of spherical lenses. Care must be taken that the two lenses are so placed that their axes coincide.

A Sphero-cylindrical Lens is equal in refractive effect to two cylindrical lenses with their axes perpendicular to each other. Having found that axis across which motion is least rapid, we may neutralize the motion with a spherical lens and, holding these two together, proceed to neutralize the motion across the other axis just as if dealing with a simple cylinder. When our object is not to determine the strength of an unknown lens, but to see if the lenses of a pair of spectacles agree with the prescription previously written, we may, of course, shorten the above procedures by picking out from the test case the glass, or glasses, which will neutralize the spectacles if the latter are of the proper strength, and observing whether the apparent motion of objects ceases when they are held together.

Locating the Optical Center.—Every glass before being worn should be examined with regard to the position of the optical center of each lens and the distance of these from each other, as inaccuracy in this important particular

is not uncommon. Indeed, in the cheap spectacles which some persons unfortunately buy, proper centering is the exception. In grinding large numbers of lenses by machinery a certain number in each batch are, I believe, always found to be badly centered. These are not returned to the wheel or the furnace by the thrifty manufacturer, but are graded as second class, or if very bad indeed as third class, and with those which will not pass inspection in other particulars go to make up the trash sold by peddlers.

A simple way to find the location of the optical center is to hold the lens about a foot above the corner of a rectan-

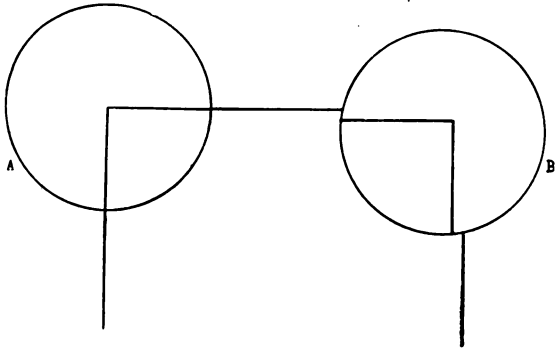


FIG. 40.

gular card lying on the table. The corner seen through the lens will only appear complete and continuous with the rest of the card when its tip is opposite the optical center.

In Fig. 40, A represents a lens so held that its optical center is marked by the corner of the underlying card; B is a lens improperly held. The center first found may be marked with a speck of ink, the center of the other spectacle glass found in the same way, and the distance between them measured. If care is taken to hold the glass exactly level and the eye directly over it this method will give results accurate enough for most purposes.

The Apex of a Prism may be determined by viewing through the glass fine lines crossed at right angles, holding the prism so that its edge and supposed apex just touches one line at the point of intersection. When the real apex of the prism coincides with the intersection of the lines, the appearance presented is that shown in Fig. 41; when, however, the apex is to one side of the point of intersection, the line seen through the prism appears broken, as in Fig. 42. In this case the prism is to be rotated until the line appears continuous, when the point of intersection of the lines will mark the apex of the prism.

The Strength of a Prism may be expressed in two ways; either in degrees of the refracting angle, which is the angle

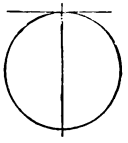


FIG. 41.

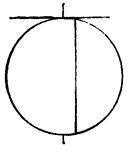


FIG. 42.

METHOD OF FINDING THE APEX OF A PRISM. (*After Maddox.*)

forming the edge and separating the two refracting surfaces of the prism, or by means of some formula which denotes the power of the prism to turn a ray of light from its course. This power is usually expressed in degrees of the angle of deviation, which is the angle separating the course of a ray of light after having passed through the prism from that which it would have pursued had its course been unobstructed. The obvious advantage of the latter mode of expression, which gives directly the optical strength of the prism, over the former, which merely states the value of a physical angle from which the strength can be more or less accurately inferred, has called forth several suggestions for an improved method of numbering ophthalmological prisms. Dr. Edward Jackson was the first to

point out that the prism had escaped attention when the numeration of our other glasses was reformed. He proposed that in harmony with the mode of stating the value of angles which is commonly accepted in other departments of science, they be marked in degrees of their angles of deviation. With the idea of conforming their numeration to the dioptric system of numbering lenses, Mr. C. F. Prentice proposed to adopt as a unit that prism having the power necessary to produce one centimeter of deviation in the course of the ray after having passed through and the distance of one meter beyond the prism. Dr. S. M. Burnett proposes that this unit be called the prism diopter, and that the centimeter of deviation be measured upon a plane surface—that is, upon a tangent of the arc whose radius is one meter.

Within practical limits the objections which have been raised to the prism diopter are few and of little moment, and it has great simplicity to recommend it. In a series of prisms so numbered, however, the higher prisms are not simple multiples of the lower ones. Twenty prisms of two P. D. each would not be equal to a prism of 40 P. D., but to a prism of 42 P. D.

The *centrad* as a unit of measurement of prism power was suggested by Dr. W. S. Dennett. After mature consideration this unit has been formally recommended by the American Ophthalmological Society, and will doubtless in a few years entirely, as it has already to a great degree, displace the old system of numbering.

The term *radian* denotes in mathematics a portion of the arc equal to the radius. The *centradian* is the one hundredth part of the radian. The centrad is such a prism as, held with one surface perpendicular to the incident ray, causes a deflection equal to a centradian. If the measurement be made at one meter, then, the radius and radian being each one meter long, the centradian will equal a

centimeter, measured on the arc, and the centrad is such a prism as will produce this amount of deflection. If the measurement be made at two meters—a very convenient distance—one centrad will produce a deflection of one hundredth of two meters, or two centimeters.

It will be seen that the practical difference between a centrad and a prism diopter consists in this, that in the

TABLE VI.—SHOWING THE EQUIVALENCE OF CENTRADS IN PRISM DIOPTERS AND IN DEGREES OF THE REFRACTING ANGLE (INDEX OF REFRACTION 1.54).

Centrads.	Prism Diopters.	Refracting Angle.
1	1	1°.00
2	2.0001	2°.12
3	3.0013	3°.18
4	4.0028	4°.23
5	5.0045	5°.28
6	6.0063	6°.32
7	7.0115	7°.35
8	8.0172	8°.38
9	9.0244	9°.39
10	10.033	10°.39
11	11.044	11°.37
12	12.057	12°.34
13	13.074	13°.29
14	14.092	14°.23
15	15.114	15°.16
16	16.138	16°.08
17	17.164	16°.98
18	18.196	17°.85
19	19.230	18°.68
20	20.270	19°.45
25	25.55	23°.43
30	30.934	26°.81
35	36.50	29°.72
40	42.28	32°.18
45	48.30	34°.20
50	54.514	35°.94
60	68.43	38°.31
70	84.22	39°.73
80	102.96	40°.29
90	126.01	40°.49
100	155.75	39°.14

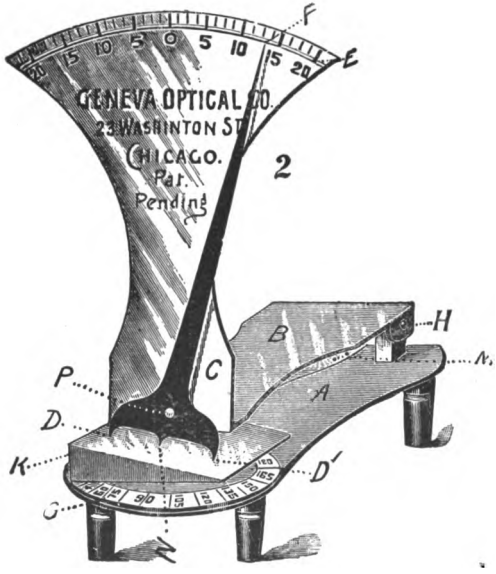
former the amount of deflection is measured on the arc, while in the latter it is measured on the tangent. For ophthalmological prisms, which are of necessity weak, the difference between centrads and prism diopters is so slight as to be of no moment. The numeration of prisms by centrads has the advantage that it is founded on a method of stating the value of the angle which is used in other departments of physics. Its higher numbers in the scale are, moreover, simple multiples of the unit.

Over the system of numbering prisms in degrees of the refracting angle the use of the centrad has all the advantages possessed by the modern numeration of spherical lenses over the old. Its use, moreover, involves no perplexity in the mind of one who has become habituated to the former method, since, as shown in Table VI the difference in value of one of the old and one of the new prisms of the same number is slight for the weaker, more used prisms. The one, however, represents a definite, fixed value; the other does not.

As the surgeon has a choice of two essentially different methods of numbering, so, also, he has at his command several modes of determining the strength of unknown prisms, and may select that one which is simplest and involves least calculation for the numeration which he uses. The refracting angle may be readily found by means of Table III, introduced when speaking of the prismatic equivalent of decentered lenses. The situation of the optical center is to be marked upon a spherical lens of convenient strength, and the prism to be tested superimposed. By viewing the corner of a card through these two glasses, as was directed in describing the method of finding the optical center, this center will be found to have been carried toward the base of the prism. The position of this apparent optical center is to be likewise marked upon the spherical lens, and its distance from the true one

measured. In the left-hand column of Table III find the strength of the lens used, and on a level with this across the page the distance in millimeters between the true and apparent optical centers. At the head of the column in which this measurement is found will stand the strength of the prism with which the lens was combined, this strength being expressed in degrees of the refracting angle. For

FIG. 43.



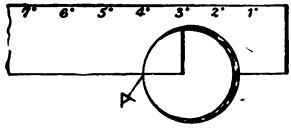
instance, if having combined an unknown prism with a + 7. D. lens we find the apparent displacement of the optical center to be 4 mm., the table shows at a glance that the refracting angle of the prism tested had a value of 3°.

The refracting angle may be directly measured by adapting the legs of a pair of compasses to the two refracting surfaces and then laying the compasses on an

ordinary protractor. Various other mechanical contrivances have been invented for effecting the same purpose, one of the best of which is represented in Fig. 43. It consists of a bed-plate A, upon the front of which is affixed a degree-circle G, and hinged to A at H is the upper plate B held up by the spring M, not plainly shown because it is under B. The upright face-plate C stands at right angles to B. On top of C is the degree-circle E. The index finger F with the lower part D D′ is made of steel and pivoted at P to swing easily over any portion of the dial plate. In measuring a prism, the position of the index finger F will be governed by the difference of the thickness of the lens at the points D and D′, and the degrees of the refracting angle of the prism will be indicated on the scale E by the pointer F.

The surgeon is, however, very little concerned with the refracting angles of prisms, except as they are the basis of the old system of numbering, which will doubtless soon be superseded by one in which the number of the prism shall

FIG. 44.



express in centrads the power which that prism possesses of causing deviation in a ray of light. One of the simplest and most convenient devices for measuring this power is that suggested by Dr. Maddox. It consists of a strip of cardboard suspended horizontally on the wall on a level with the eyes of the observer. The upper border of the card (Fig. 44) is marked from right to left with a scale of degrees, or rather tangents of degrees, proper to the distance at which the prism is to be held from the card. In Table

VII is given the distance from the right-hand border of the card of the mark for each degree of deviating angle. With the help of this table one may readily construct the scale, using column A if he elect to work at six feet, or column B if a two-meter range be preferred.

To practice this method of prismetry, the glass to be tested is held at the proper distance from the card, its apex to the left, and its upper border just below the figures of the scale, as in Fig. 44. The observer's eye being placed behind the prism, the right vertical border of the card appears displaced toward the observer's left and points upward to the number expressing the strength of the prism in degrees of the angle of deviation. During this maneuver care must be taken that the prism is held at precisely the distance from the card for which the scale of the latter is arranged; also that the apex of the prism points exactly to the left. This latter requirement may be secured by rotating the

TABLE VII.*

For Marking a Card in Tangents of Degrees at 6 Feet (Column A); or 2 Meters (Column B).					
	A	B		A	B
1°	1.25 in.	3.49 cm.	9°	11.4 in.	31.29 cm.
2°	2.5 "	6.98 "	10°	12.6 "	34.73 "
3°	3.7 "	10.467 "	11°	14.0 "	38.16 "
4°	5.0 "	13.95 "	12°	15.3 "	41.58 "
5°	6.3 "	17.43 "	13°	16.6 "	44.99 "
6°	7.57 "	20.9 "	14°	17.9 "	48.38 "
7°	8.84 "	24.37 "	15°	19.3 "	51.76 "
8°	10.12 "	27.83 "	16°	20.64 "	55.13 "

prism until the line of the bottom of the card appears unbroken, as at A, in Fig. 44. In adapting this method of prismetry to centrads or prism diopters, the scale at the top of the card should simply be laid off in centimeters, and

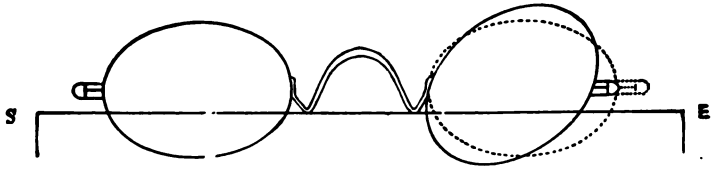
*From Maddox: "The Clinical Use of Prisms."

the prism be held at the distance of one meter. Each centimeter that the right border of the card is apparently moved to the left, on viewing it through the prism, will then represent one centrad, or one prism diopter.

Scratches, Specks, Bubbles, Flaws, etc., in the glass will hardly escape detection if they are carefully looked for while the lens is held in different lights. Placing the glass against a dark background and allowing a bright light to fall obliquely upon it will perhaps bring them out as plainly as any other maneuver.

Irregularity of the Surface may be discovered by reflecting from that surface any object having regular outlines. The observer should stand facing a window, holding the lens against a dark background in his left hand, and pass a straight-edged piece of paper held in his right hand between his eyes and the lens. Two images of the paper will be reflected from the lens—one formed by each surface. Any irregularity of these surfaces will make the images appear broken, or with wavy outlines.

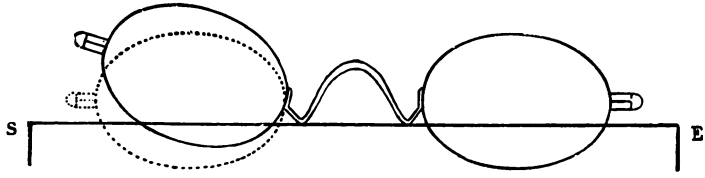
FIG. 45.



Adjusting Spectacle Frames.—It requires some little practice to enable one to tell at a glance just where such an irregularly shaped object as a spectacle frame has been wrongly bent; having found the error, it is a more simple matter to correct it. For the latter purpose two small pliers are required. They should have narrow but strong jaws, round in one pair and square in the other. As found in the shops, the grasping surfaces of the jaws are generally

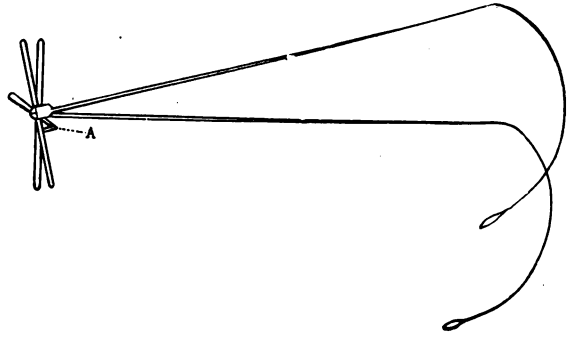
roughened, but should be smoothed off with a file, lest they scar the gold when in use. A small, stout screw-driver with a point suited to the screws of spectacles will also be necessary.

FIG. 46.



Eye wires are generally of such light material as to take their shape from the contained glass, and are, therefore, not liable to become misshapen. Sometimes the long axis of an oval eye gets rotated within the eye wire (Fig. 45), so that it no longer stands squarely across the face. By loosening

FIG. 47.



the screw it can readily be re-adjusted. Abnormal crookedness about the bridge is best disclosed by placing a straight edge (indicated by the line S E in Figs. 45, 46, 48, 49 and 50) in such a position as to enable one to compare the two sides of the frame. If the bridge is bent at its junction

with the eye wire a rotation results, looking very much like that just mentioned, but dependent upon an entirely different fault (Fig. 46). It is readily corrected with pliers or fingers.

The planes of the glasses may cross each other (Fig. 47), in consequence of a twist in almost any part of the bridge,

FIG. 48.

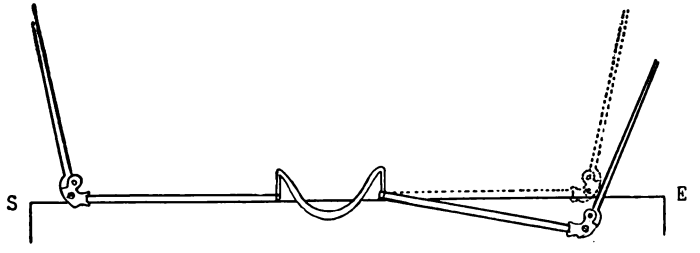


FIG. 49.

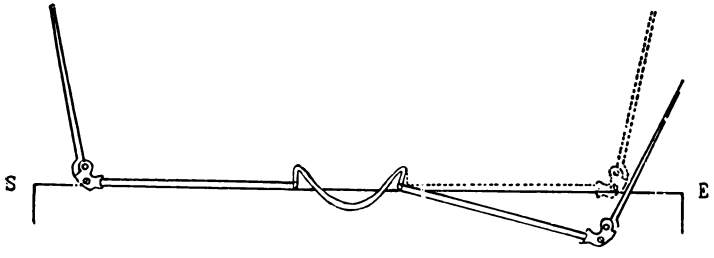
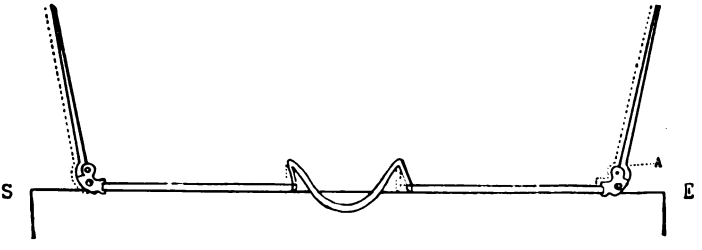


FIG. 50.



though the trouble is, usually, that the angle of the bridge at A is not of the same size as its fellow of the opposite side. The bridge is inclined, as shown in the cut, more to one glass than to the other. It requires application to the patient's face to determine which is the proper inclination, and in order that the glasses may be equalized at this and not at the improper one.

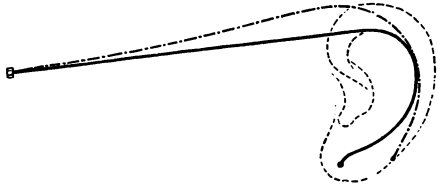
In Fig. 48 the bend is at the junction of the eye wire with the bridge, rendering corresponding angles of the two sides of the frame unequal. The diagram shows the change necessary to correct the trouble. A similar fault is shown in Fig. 49. This appears at first sight to be just like the last; it is, however, a neighboring angle of the bridge which needs equalizing with its fellow.

In the frame represented in Fig. 50 the glasses lie in the same plane, but one of them is nearer the center of the bridge than the other, due to the fact that, of the angles of the bridge which can be seen by viewing the frame in this position, the two which lie on one side of the curved portion are too much open, while the two on the other side are too little so. Of course, the bridge may be misshapen in any portion of its extent, but the illustrations given are sufficient to show the sort of faults one may expect.

Having rectified all want of symmetry in the "front," the defects in the fit of the temples can best be corrected by trying the frames on the patient's face. If on doing so it is found that their temples cut into the temples of the wearer, instead of just touching the skin, as they should do, the trouble is obviously that the distance between the temples is too small, and they must be bent out at the hinges, so as to throw them, when open, farther apart. This is done with the square-jawed pliers, seizing the wire close up to the hinge. When the opposite condition pertains, that is, when the distance between the temples is too great, leaving a space between each wire and the side of the

wearer's head, they require to be bent in. To do this, take the end of each side in turn in the square-jawed pliers, in such a way that the edge of one jaw shall be in contact with the temple as close to the hinge as possible and the latter be held rigidly open. The temple may then be pressed in with the fingers, and will bend at the point where it is pressed against the edge of the pliers. If the latter are rightly placed this does not make an angle in the wire forming the temple, but simply alters the angle already formed at A in Fig. 50, by the expansion of the end of the temple to help form the hinge. Care must be taken that one temple is not bent out more than the other, or, as is apt to be the case, become so during use. When this happens the

FIG. 51.



effect is quite different from what might be expected. The glass on the same side as the temple the more bent out will be brought closer to the eye, while its fellow will be carried farther forward and the bridge will ride obliquely across the nose. To remedy this it is only necessary to equalize the divergence of the temples.

The curve of hook temples given them by the maker will rarely be found to fit comfortably behind the ear. As has been pointed out by Dr. Charles H. Thomas, the proper form for hook temples is a straight line from the hinge to the top of the ear, where a sharp curve should join this part of the temple to the easy curve which corresponds to the back of the ear (Fig. 47). Where the curve given the hook

is too wide and is extended upon that part of the wire resting against the patient's temple, as shown by the dotted line in Fig. 51, there is a constant tendency of the spectacles to slide forward. The wire, moreover, touches the back of the ear for a short distance only, where its pressure is further increased by the fact of the whole temple being put upon the stretch and acting as a spring. Especially at first should the frames not fit too tightly, as the skin is then more easily irritated by the wire than when it becomes accustomed to its presence.

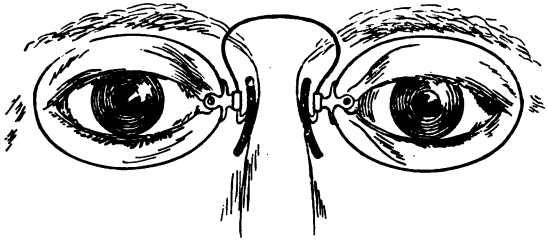
In persons whose ears stand out far from the head a certain ridge upon the cartilage of the ear is thrown into prominence. Since the curve of a hook temple is a regular one, it will rest upon this ridge and be very uncomfortable; indeed, it may cut through the skin and into the cartilage. Under such circumstances the portion of the wire which is behind the ear should be made to follow every depression and elevation of the surface with which it is in contact; as it should in any case where the auricle is deformed or irregular in any way.

If one lens stands higher upon the face than the other, so that the patient looks through the upper part of one glass and the lower part of the other, it will be found that the temple on the side which stands the higher is turned down more than its fellow. It should be raised, or more frequently its fellow should be lowered. The fault may lie in the bridge, as shown in Fig. 47, or in the end piece, or in the temple itself. In the first instance, bringing the lenses into the same plane removes the difficulty; in the second, take the end piece in the round-jawed pliers, the jaws being applied to its edges close up to the eye wire. Holding these pliers in the left hand, apply the square jaws of the other pliers to the surfaces of the end piece; when, by twisting the latter about its long axis, the temple may be turned down to any desired extent. Thus, the temple

is not bent at all, but the end piece between the hinge and the eye wire. Nearly the same effect may be produced by bending the wire of the temple close up to the hinge. As was remarked before, in speaking of the facing of the glasses, the effect of turning down both temples is not to make both lenses stand higher upon the face but to make the glasses face more downward.

Sometimes when the glasses do not sit properly the trouble will be found to be not in the frames but in the wearer. A considerable amount of asymmetry of the two sides of the face is not uncommon. One ear or one eye

FIG. 52.



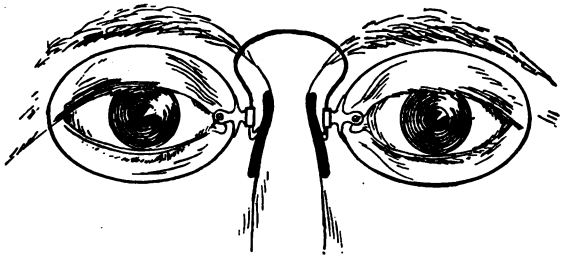
may be higher than its fellow, either of which conditions will make the glasses seem awry, and render necessary a compensating asymmetry of their frames.

Adjustment of Eyeglasses.—The starting-point in adjusting eyeglasses is at the nose-pieces, whose free surfaces should be made to conform accurately to the bones of the nose by which they are supported. When received from the maker they are generally curved, presenting a convexity toward the nose. As the bones of the sides of the nose at the point where the guards are to rest are usually more or less convex also, the bearing obtained is a most insecure and uncomfortable one, as a glance at Fig. 52 will show. In Fig. 53 this glass is shown with its nose-

pieces properly adapted to the sides of the nose. Any conformation may be required, but that shown in Fig. 53 is the one most frequently needed. These changes in the shape of the nose-pieces are readily effected by means of the pliers, especially if the nose-pieces recommended in Part I are used. When the guards are of cork, care must be taken that they are not scarred and broken by the pliers, and a special tool with a longitudinal groove in the jaws for grasping the sides of the nose-pieces is here of service.

It will be readily seen, moreover, that the nose-pieces must incline equally to a vertical plane passing through

FIG. 53.

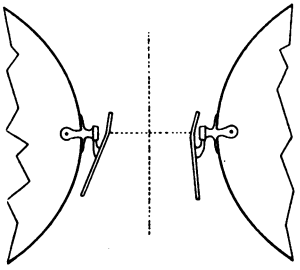


the center of the nose; otherwise the glasses will stand awry; that is, provided the nose is straight and its two sides alike. In a large proportion of cases, however, a plane through the middle of the nose is only approximately vertical, so that one nose-piece must be inclined more than the other. (Fig. 54.) It is even necessary, sometimes, to incline the top of one nose-piece toward the vertical plane and the other away from it.

The slope of one side of the nose from the crest backward is frequently steeper than that of the other side. A symmetrical eyeglass on such a nose will stand with one lens close to the corresponding eye and the other standing forward away from the eye. One nose-piece will tend to

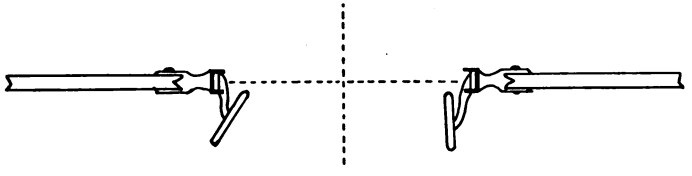
rest on its anterior edge and the other on its posterior edge. By partially revolving each nose-piece around the long axis of its bearing surface the glasses are brought parallel to the general plane of the face and each nose-piece presses evenly over its whole bearing surface. Fig. 55 is intended to il-

FIG. 54.



lustrate what is meant. It is a diagrammatic view from above, showing the ends of the nose-pieces as arranged for a case in which the bridge of the nose does not slope equally on the two sides. These changes in the inclination of the nose-pieces are brought about by bending or twisting the foot at the point B in Fig. 56.

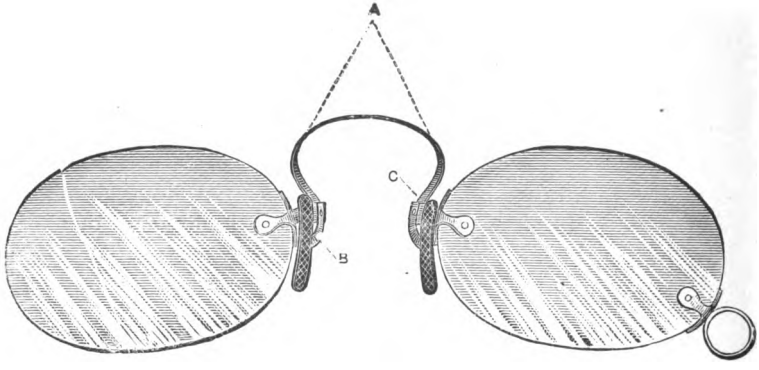
FIG. 55.



Having conformed the nose-pieces to their bony support, the tension of the spring by which they are pressed against the sides of the nose is to be regulated, the object being to have just sufficient force exerted to keep the guards securely in place. If the latter are properly fitted the

amount of pressure necessary is not great. Though this pressure should be evenly distributed over the surfaces of the nose-pieces, want of firmness in the "pinch" of their tops is particularly fatal, as the lower ends then become the principal support of the weight of the glasses, rendering them prone to topple forward and fall. To increase the tension of the spring, and consequently the pinch of the frames, the curve of the spring included between the lines at A, in Fig. 56, should be made more arched and rounded. Conversely, the force of the spring is lessened

FIG. 56.



by flattening this arch. Any alteration in the shape of the spring, however, while it does not, of course, change the shape of the nose-pieces, does change the angle at which they are inclined to each other. For instance, if the spring be made more arched, the nose-pieces are brought nearer together, but the bottoms are especially approached toward each other. When the spring is flattened the bottoms of the nose-pieces are thrown proportionately farther apart than the tops. It follows that with each adjustment of the tension of the spring the inclination of the nose-pieces must

be rectified. This is easily accomplished by twisting the "foot" or support of the nose-piece at B in Fig. 56.

When the points mentioned have been properly adjusted, the long axis of one or both glasses may fail to stand squarely across the face as it should do. The remedy lies in an appropriate bend of the spring at the point C (Fig. 56). This also requires a slight re-adjustment of the inclination of the nose-pieces to each other.

The distance between the centers of eyeglasses is determined (the distance between the nose-pieces when in use being a fixed quantity) by the distance of the nose-piece on each side from the center of the corresponding eye. The intercentral measurement may therefore be varied by varying the size of the eye used, and by altering the distance of the nose-pieces from the edges of the lenses by an appropriate bend of the foot B (Fig. 56), or by using a longer or shorter stud. The distance of the glasses from the eye is controlled by the length of the foot B, and in the better grades of goods this part is made in two or three lengths.

Eyeglasses seldom stand too low upon the face but they frequently have the fault of standing too high, especially for near work. The neatest way of lowering them, but one which must be attended to when prescribing them, is to have the studs attached above the horizontal diameter of the lens, instead of at that diameter, as is usual. They may thus be lowered one, two or three millimeters; or a special form of nose-piece may be used. (Fig. 16.) It is sometimes necessary to combine these methods.

The Care of Spectacles.—Spectacle frames will last longer and perform their function better if the wearer is instructed to exercise care in handling them. In putting them on and off, the hooks should be lifted from or into their position behind the ears; both hands being used, so as to avoid straining the temples widely apart or otherwise bending them. They should be folded together as little as

possible, and when not in use should be laid in a safe place, open, and resting on the edge of the lenses, to avoid scratching the surfaces of the latter. For cleansing them nothing is better than a piece of clean old linen, or, if very much soiled, a little ammonia and water may be used, except on cemented bifocal glasses. While cleansing, the frame should be grasped by the end piece and not by the bridge, and in replacing the glasses on the eyes care should be taken not to crush them against the lashes and thus soil the refracting surfaces at once. When cylindrical or prismatic glasses are worn, patients may return after a time with the statement that the spectacles are unsatisfactory, when the trouble will frequently be found to be due to bending of the frame; or a lens may have fallen out and been replaced upside down, or with the wrong edge inward. It is well to have such persons report periodically to have their glasses re-adjusted.

INDEX.

Adjustment of eyeglasses, 83
of spectacles, 77
Airy, discoverer of astigmatism, 7
Alhazen, 3
Ancient glass, 1
Angle, deviating, of a prism, 71, 75
refracting, 70, 73
Angle of crest of bridge, 59
Apex of a prism, finding the, 70
Assyrians, knowledge of lenses among, 2
Astigmatism, discovery of, 6
Asymmetry of the face, 83

Bar spring eyeglasses, 32
Bifocal glasses, 26
invention of, 7
varieties of, 26
Brewster, Sir David, 2, 6
Bridge, width of base of, 59
relation of top of to plane of glasses, 44, 58
height of, 57
Bridges, manufacture of, 21
varieties of, 23

Care of spectacles, 88
Cemented bifocals, 27
Centering and decentering, 36
normal lateral, 41
normal vertical, 43
of spectacles for constant use, 42
near work, 42, 44
Centrad, 39, 71, 76
Chemical composition of glass, 12
Component parts of spectacles, 11
Conformation of nose-pieces, 83
Crest measure, 60
Crown glass, 12
Cylinder, finding the axis of, 67

Date of invention of spectacles, 4
Decentered lenses, 36
prismatic effect of, 38
Deviating angle of a prism, 71, 75
Dioptric system, 17
Di Spina, Alessandro, 5
Discovery of astigmatism, 6
Distance between the pupils, 36, 51
between temples, 80
of the glasses from the eyes, 44

Emerald used by Nero, 2
Epicanthus, eyeglasses for, 35
Eyeglasses, advantages and disadvantages of, 9
inspection and adjustment of, 62, 83
prescription of, 62
varieties of, 30
Extra front, 30
Eye wires, manufacture of, 21

Face, asymmetry of, 57, 60, 83
Facing of spectacles, 47
Focal length of lenses, 63
Frames (see spectacle frames)
Frameless spectacles, 22
Franklin, inventor of bifocal glasses, 7
glasses, 26
Fused bifocals, 28

Geometrical center, 36
Glass, chemical composition of, 12
ancient, 1
Ground bifocals, 28

Height of bridge, 57
Hook temples, 23, 81

Index of refraction, 13
Inspection and adjustment of spectacles, 63
Interpupillary distance, 36, 47, 51
Introduction, 1
Invention of spectacles, 4
Irregularity of surface of lenses, 77

Kepler, Johann, 3

Lateral centering, 41
Lathe for grinding lenses, 17
Lens cutter, 19
    oldest known, 2
Lenses, decentered, 36
    finding focal length of, 63
    forms of, 13
    known to the ancients, 2
    material of, 12
    method of grinding, 17
    neutralization of spherical, 66
        cylindrical, 67
        sphero-cylindrical, 68
    numeration of, 17
    proving the strength of, 63
    toric, 20, 49
    tilted, 45
Lenticular segments, 27
Locating the optical center, 68
Lorgnettes, 9

Maddox pupil localizer, 55
Marking of gold spectacle frames, 10
Material of lenses, 12
    of spectacle frames, 9
Meniscus, 14

Natural position for spectacle bridge, 43
Nero, concave jewel used by, 2
Neutralization of spherical lenses, 66
        cylindrical lenses, 67
        sphero-cylindrical lenses, 68
New system of numbering lenses, 17
Normal position of spectacles, 36
Nose-pieces, conformation of, 83
Numeration of lenses, 17
    of prisms, 70

Offset guard, 33
Oldest known lens, 2
Old system of numbering lenses, 17
Opticians' lathe, 17
Optical center, 36
        locating the, 68

Pebble spectacles, 12
Periscopic glasses, 20, 48
Pince nez (see eyeglasses)
Phacometers, 64
Plane of the glasses, relation to the visual axis, 45
Prism diopter, 71
    finding the apex of, 70
    deviating angle of, 70, 75
    refracting angle of, 70, 74
    numeration of, 70
Prismatic effect of decentering, 38
Prismetry, 73
Prescription blank for spectacles, 53
    of eyeglasses, 62
    of frame, 51
Proving the strength of lenses, 63
Principal axis, 36
Principles of spectacle fitting, 36
Pupil localizer, 55
Pupillometer, 56

Quizzing glasses, 9

Refracting angle of a prism, 70, 74
    surfaces, 13
Rigid frame eyeglasses, 32
Rock crystal, 1, 12
Romans, knowledge of lenses among, 2
Rule for measuring frames, 53

Saddle bridge, 23
Salvinus Armatus, 4
Scratches, specks, flaws, etc., in glass, 77
Segments, lenticular, 27
Signs used in prescription writing, 16
Spectacle eyes, sizes of, 24
        shapes of, 24
    fitting, principles of, 36
    frames, adjustment of, 77
    material of, 9
    marking of gold, 10
    prescription of, 51
    rule for measuring, 53
Spectacles, component parts of, 11
    bifocal, 26
Spectacles, care of, 88
    date of invention of, 4
    early references to, 4, 5
    for cosmetic effect, 35
    invention of bifocal, 7
    inspection and adjustment of, 63

Spectacles, frameless, 22
facing of, 47
patterns of, 22
pebble, 12
periscopic, 20, 48
reversible, 24
St. Jerome's eyeglasses, 5
Surface, irregularity of, 77

Temples, distance between, 80
manufacture of, 21
varieties of, 23
Tilted lenses, 45
"Tool" for grinding spherical lenses, 17
Tools for adjusting frames, 77
Toric lenses, 20, 49
Transparent glass found in Nineveh, 1
Trial frames, 51, 62

Vertical centering, 43
Visual axis, relation of plane of the glasses to, 45

Width of base of bridge, 59